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White, James A.

University of Kansas

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DEVELOPMENT OF A MODIFIED PACER SIMULATION PROGRAM FOR USE IN A CHEMICAL ENGINEERING CURRICULUM

JAMES A. WHITE

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DEVELOPMENT OF A MODIFIED PACER SIMULATION PROGRAM FOR USE IN A CHEMICAL ENGINEERING CURRICULUM

by

James A. White

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ABSTRACT

The author employs a 16K linked, FORTRAN II version of the problem oriented PACER simulation program written by Prof. Paul T. Shannon, Dartmouth College, Hanover, New Hampshire to develop a non-linked, FORTRAN IV program which is compatible with the GE 625 system installed at the University of Kansas.

The author then formulates a steam power system model and tests several configurations of this system to demonstrate

(1) the efficacy of the modified PACER program and

(2) the potential usefulness of such a modified PACER program in either graduate or undergraduate chemical engineering curriculum.

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Chapter I

INTRODUCTION

General. In early 1965 the National Science Foundation established a project at the University of Michigan to evaluate the current and future uses of computers in engineering design education. The final report issued by this project observed that the majority of analytical work done in upper-level engineering courses was of a routine nature, where the solution procedures are generally brief and straightforward and where there is normally only one correct answer. For this reason, the report stated, engineering design courses had fallen into general disregard and in some instances they have been eliminated from the curricula. Rather than take a pessimistic view from these circumstances, the report concluded that:

> Such courses can, with the introduction of the computer, take on a new luster and make significant contributions to the education of our engineering graduates. In the past, the engineering student has only had time to investigate perhaps one or two possible (and usually not very effective) designs. With the new hardware and software systems, the student designer will for the first time have the opportunity to investigate a large number of feasible solutions to his design problem....
>
> In effect, because of his exposure to a large number of designs and his ability to manipulate system configurations and design variables easily, the student can gain some facets of "engineering experience" which cannot now be acquired outside the industrial environment (and which would require a much longer elapsed time). Thus, in addition to its use as an analysis tool, the time shared computer with appropriate design-oriented software should enable the student to improve his intuition and understanding of the nature of good design: this is the raison d'etre of engineering design courses.[1]

One of the most promising approaches to the demand for effective engineering design education lies in the recent development of problem-oriented approaches to programming languages. The problem-oriented approach involves the development of a general processor or executive program which is capable of handling a general class of problems with a minimal amount of programming effort on the part of the problem

designer. This frees the designer to concentrate on the primary objective of system design and analysis.

Of the problem-oriented simulation programs developed thus far, one of the most notable is PACER. PACER was developed by Prof. Paul T. Shannon of Dartmouth College and was developed primarily to process material and energy balances of typical system design problems encountered in chemical engineering. Solutions are processed by a modular or unit operations concept with iterative calculations undertaken when recycle conditions are encountered.

Objective and Scope of Thesis. This thesis will examine the historical development of digital simulation programs culminating with the development and some applications of PACER. The essential concepts and characteristics of PACER as developed by Prof. Shannon will be described and illustrated. The author will further discuss the modifications made to PACER to make it compatible with the computation system installed at the University of Kansas. Additionally, the author will trace the development of a semi-realistic model of a steam power plant developed to evaluate the modified PACER program. As a related objective, the usefulness of the model in an undergraduate chemical engineering education curriculum will be explored.

Finally, the advantages and limitations of the modified PACER program and suggestions for its further improvement and refinement will be presented for consideration.

Chapter II

HISTORICAL DEVELOPMENT OF DIGITAL SIMULATION PROGRAMS AND APPLICATIONS TO ENGINEERING EDUCATION

Historical Development of Digital Simulation Programs. Initial attempts toward computer simulation of chemical engineering systems, were made in the early 1950's and were limited almost solely to analog computers. The digital computer at that time required tedious machine-language programming and it was slow and expensive for such uses. Accordingly, it could not effectively compete with the analog computer.[2] (Figure 1 presents a schematic illustration of the historical development of simulation programs).

R. G. Selfridge is generally credited with the development, in 1955, of the first digital simulation program for use on the IBM 701 computer[3]. This initial effort was followed during the period from 1956 to 1958 by the development of a group of digital computers known as digital differential analyzers (D.D.A.'s). The D.D.A.'s were designed to duplicate the functioning of the analog computer, but proved to be exceedingly slow and cumbersome[4].

One of the most significant advances in digital simulation occurred with the development of procedure-oriented languages, such as FORTRAN, in the late 1950's. The availability of these languages facilitated the heretofore cumbersome programming task by permitting the programmer to write his program in terms closely resembling the symbolic representation of problem variables and parameters. A compiler converted the symbolic program into machine language instructions. The FORTRAN language additionally was provided with a library of functions and subroutines which performed commonly encountered mathematical operations such as logarithims, exponentation, etc. FORTRAN coupled with increasingly spectacular improvements in memory capability and speed of operations, where operations are currently specified in nano-seconds (billionths of a second), gradually began to assert the effectiveness of digital simulation programs.

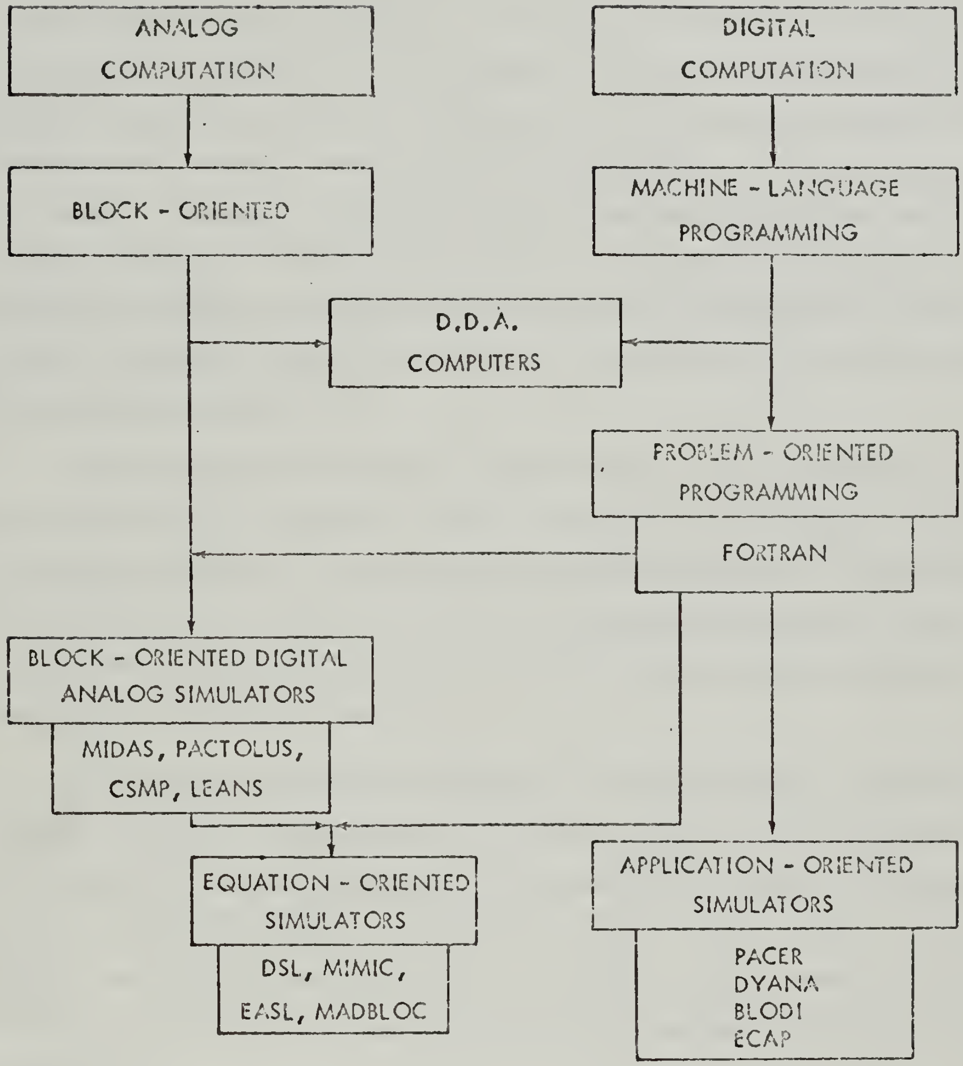


Figure 1. Development of Simulation Programs[5]

The relative advantages and disadvantages of digital and analog simulation became more distinct as each system was progressively developed. It was readily acknowledged that the analog computer enjoyed the advantage of parallel operation which obviated the careful attention to logical execution sequence and extensive anticipation of alternatives required by the sequential nature of the digital computer. Digital computers normally require extensive reprogramming for different problem structures. Mathematical integration, a natural operation for an analog computer, requires specific and extensive programming on a digital computer. On the other hand, the digital computer provides certain specific advantages which the analog computer cannot approach: greater reliability, memory and logic capabilities as well as a decidedly better dynamic range.[6]

An extensive effort was undertaken to incorporate the best features of the analog and digital computer into a digital simulation capability referred to as a digital-analog simulator. These simulation systems generally consist of block-oriented subroutines which perform or simulate the natural functions of an analog computer such as integration and differentation.

Two representative examples of digital-analog simulators are the MIDAS and MIMIC programs. The most significant capability of MIDAS[7] is its integration function which automatically adjusts the integration step to a specified size and combines this feature with a fifth-order Milne, predict-correct integration routine. These characteristics provide the user with assurance that the integration is being performed correctly.[8]

The next effort in digital simulation involved the development of equation-oriented, digital-analog simulation programs which did not rely upon the block-oriented structure imposed on MIDAS and its contemporaries. Chief among this group of programs were DSL/90[9] and MIMIC.[10]

MIMIC, introduced in 1965 by the authors of MIDAS, differs in concept from the less flexible block-oriented MIDAS. MIMIC offers several other features not comparably available in MIDAS, such as

a wider variety of available subroutines, FORTRAN compatibility and intuitive solution capability for implicit algebraic equations.[11]

A separate class of programming languages has been designed to simulate systems characterized by a sequence of discrete events such as schedule optimization and resources allocation. Representative examples of this type of program are GASP,[12] GPSS,[13] SIMSCRIPT,[13] and CSL.[13]

The most significant current advance in the field of digital simulation is the development of problem-oriented or application-oriented programming languages which are designed to handle a specific class or specific classes of problems. Some of the more significant of this type of program are:

1. BLODIB[14] and ECAP[15] for signal analysis and circuit design in electrical engineering
2. DYANA[16] for vibration analysis in mechanical engineering, and
3. PACER[17, 18] for system simulation in chemical engineering.

PACER, an acronym for Process Assembly Case Evaluator Routine, was conceived in 1961 by Prof. Paul T. Shannon while he was in the employ of Humble Oil and Refining Company. After extensive modification and development, PACER received its first practical test in October 1964 when Prof. Shannon joined with Prof. A. I. Johnson of McMaster University, Hamilton, Ontario, Canada and Dr. Norman Cooke from Canada Industries Ltd. to undertake a simulation of C-I-L's 300 ton/day contact sulfuric acid plant in Hamilton. This initial undertaking was successfully completed and reported in April 1965. The sulfuric acid plant simulation involved the use of 42 equipment, information gathering or parameter setting subroutines which were interconnected by approximately 70 information transmittal streams. The model thus conceived involves the solution of approximately 500 simultaneous equations involving almost 1000 stream variables and 200 equipment parameters. A complete simulation run required 8 minutes of computer time on the IBM 7040 computer.

In 1965 the staff and the senior chemical engineering students at McMaster University joined with C-I-L in the design of a 600 ton/day sulfuric acid plant based on metallurgical off-gas. The results of this study were presented to C-I-L and representatives of other companies in April 1966. Today, more than twelve industrial firms are using PACER in the analysis of their processing problems, and thirty-nine universities are integrating PACER into their teaching and research activities.[19]

<u>Use of Computers and Simulation Programs in Engineering Education</u>. In 1959 the College of Engineering of the University of Michigan undertook, under the sponsorship of the Ford Foundation, a study of the feasibility of broad scale integration of electronic computer use into the educational process. The final report of this study recommended that:

> (1) All engineering students be introduced to computing techniques early in their college education, preferably at the freshman or sophomore level.
> (2) That they develop a proficiency in a procedure-oriented language such as FORTRAN, ALGOL, MAD, etc., and
> (3) Required upper-level engineering courses incorporate the requirement for computer solutions of several engineering problems of graded difficulty by the student prior to graduation.[20]

A disciplinary appendix to the final report entitled "The Use of Computers in Chemical Engineering Education" cited the purely educational aspects of computers in the education process, stressing the salutary effects of precise formulation, definition, and logical organization required for computer solution of engineering problems.

A survey of engineering school deans and department heads taken in 1962 as a part of the Project revealed that approximately 30% of all engineering students attended schools which had a required introductory computer course for undergraduate students. The study further indicated 45% of engineering students attended colleges or universities which required students in some engineering disciplines to attend such an introductory course. A subsequent study conducted during the 1965-66 academic year showed that approximately 87% of all engineering undergraduate students received some required

instruction in digital computer techniques. An analysis of this data indicates that in the near future almost all undergraduate engineering students will attend a required digital computer introductory course.[21]

Quality, however, apparently has not matched quantity as the summary report on "Computers in Engineering Design Education" concluded. (See Chapter I). Most of the computer solutions assigned in upper level engineering courses are routine in nature. One major shortcoming in the field of engineering design has been traditional reticence of design instructors to employ sophisticated mathematical analysis techniques in their courses. Further, existing computer hardware and programming languages, due primarily to their general nature, were not amenable to flexible use in design problems.

However, two recent developments in the field of computer technology hold the promise of a vast improvement in the area of engineering design education. The first of these new developments is the time-shared computer with remote terminal installations. These facilities will permit a large number of users to have almost instantaneous access to the computer and will permit these users to communicate with the computer in an almost conversational manner. This time-sharing capability, coupled with the development of a new hierarchy of problem-oriented computer languages and processors such as PACER, permits the visualization of the investigation of a large number of feasible configurations of complex engineering problems by a student in the course of a semester. In effect, the computer will then take on the role of an effective imparter of "engineering experience".[22]

Chapter III

CONCEPT, ORGANIZATION AND OPERATIONS OF PACER

Concept of PACER. As previously mentioned PACER was developed by Prof. Shannon to provide a highly-flexible, systematic method for the simulation and design of complex chemical engineering systems and processes. The basic concepts underlying the PACER system may be summarized as follows:

1. PACER is a systematic method which permits a progressive development of comprehensive models of chemical engineering systems or processes.

2. The processing or operational sequence and the physical configuration of the system or process are included in the input data provided by the user and can be readily modified to explore alternate system or parametric configurations.

3. Mathematical models of individual equipments are available for use during development of the total system or process.

4. Earlier work and results may be incorporated into the process model with minimal effort on the part of the user.

5. The successful completion of each analysis contributes to the development of a library of mathematical equipment models which may be used in subsequent analyses.[23]

PACER conceptually then differs from a procedure-oriented language such as FORTRAN. FORTRAN permits a problem solver to write solutions for mathematical and engineering problems in a language which symbolically approximates commonly-encountered engineering and mathematical terms. It does not provide a general or even a specific solution method. It's greatest advantage lies in its flexibility--the ability to represent many types of problems, ranging from the social sciences and law to nuclear physics, with the same language.

This generality also represents a deficiency of FORTRAN. Its use, in many cases, requires the complete restructuring of complex solution programs for only minor system or problem configurations.

Such a requirement can be exceedingly cumbersome to a systems designer or analyst who is primarily interested in the results of the simulation.

PACER was developed to provide to a chemical engineer the ability to rapidly and accurately solve varying configurations of complex chemical engineering systems. PACER accomplishes this by providing a rigidly-structured program which is capable, with minimal effort on the part of the user, of solving complex chemical engineering systems. No tedious rewriting of the program is necessary for changes in configuration. PACER, then, provides the logical next step in computer language design--macro-procedure-oriented programs.

It permits a user to systematically describe (by the use of a highly-structured data deck) the topology and parametric constraints of the system to be solved. Major changes in the actual physical configuration of a system can be accommodated with relatively simple changes to the data deck. It also provides the user the option of specifying or not specifying the order in which equipment will be calculated. If the order of calculation is not specified, PACER enters into a trial and error procedure to determine the solution order.

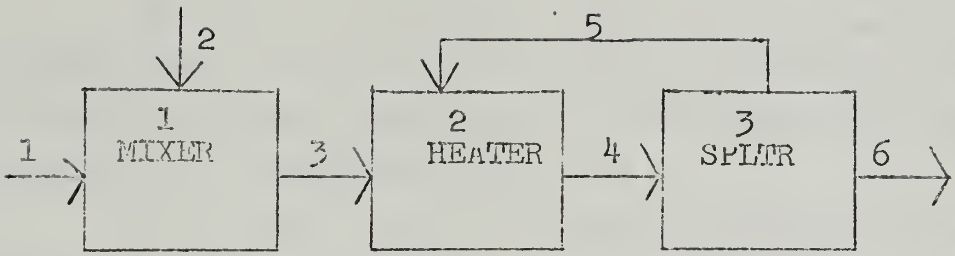
The PACER concept of operations may be effectively illustrated by the presentation of a simple problem involving (1) a flow mixer, (2) a heater and (3) a flow splitter. Figure 2 presents the flow diagram for such a system, as well as the major components of the data deck which would be used to communicate the system configuration and parametric representation to the PACER executive routine. A more extensive discussion of the data deck and its components is presented subsequently in this chapter and Appendix A.

<u>Organization of PACER.</u> The major elements of PACER are:

1. A mainline program which serves as the general processor for PACER operations and conducts all iterative calculations.

2. Information modifying and parameter setting subroutines. These include:

(a) EQCAL - Calls proper equipment subroutines to calculate system or process equipments.



a. Flow Diagram

EQPT.	STREAM NUMBERS					
1 MIXER	1	2	-3	0	0	0
2 HEATER	3	5	-4	0	0	0
3 SPLTR	4	-5	-6	0	0	0

b. Process Matrix

EQPT. NO.	EQUIPMENT PARAMETERS				
1	0	0	0	0	0
2	0	17.	350.	2.	43.5
3	0	.2	.8	0	0

c. Equipment Parameters

STREAM NO.	STREAM VARIABLES						
1.	0	15.	80.	100.	0	100.	0
2.	0	15.	60.	200.	200.	0	0
3.	0	15.	0	0	0	0	0
4.	0	15.	0	0	0	0	0
5.	0	15.	0	0	0	0	0
6.	0	15.	0	0	0	0	0

d. Stream Variables

STREAM VARIABLES ABSOLUTE FRACTIONAL CONVERGENCE CRITERIA							
1.	1.	1.	.01	.01	.01	.01	.01

e. Convergence Criteria

EQPT.	MODE
1	1
2	2
3	3

f. Equipment Calculation List

(b) TEST - if calculation is in an iterative (recycle) mode this subroutine tests the values of the output stream variables for the equipment being calculated to determine if the calculated values meet convergence criteria established by the user.

(c) XDATA - provides the space for additional equipment variables if required by the user.

(d) MAJOR - called by PACER when order of calculation of equipment is not supplied by user. MAJOR directs search for list of equipments which will calculate as output streams up to three assumed known input streams. When such a list is developed the equipments are calculated as either direct or iterative calculations depending on their configuration.

(e) EQUIP - serves as a bookkeeping subroutine for all equipments which are calculated directly. Bookkeeping functions for equipment calculated in an iterative mode are performed by the mainline program.

(f) GUESS1 - forms under the direction of MAJOR an ordered list of unknown input streams. From this list, up to three unknown streams are assumed known and a search is made to find a list of equipment which will calculate as output streams the assumed known input streams.

(g) GUESS2 - carries out under the direction of GUESS1 the search for a list of equipment which will calculate as output streams those unknown streams assumed known in GUESS1. If such a list of streams can be found, GUESS2 calls for appropriate calculation.

(h) DREAD - reads data deck for problem configuration (run). A new set of data is required for each configuration (run).

(i) EXREAD - reads additional equipment parameters if provided by user as well as order of calculation if specified.

(j) SEFLAG - sets numerical indicators (flags) indicating status of equipments and streams provided as data. Flags may indicate either that an equipment is used or not used or that a stream is a feed stream, product stream, internal stream or not used.

(k) DPRINT - prints data supplied by user. Primarily used as a debugging feature.

(l) EXPRNT - prints additional equipment parameters supplied or calculated by PACER as well as order of calculation specified by user.

(m) RPRINT - prints results of run conducted by PACER. Results are printed at completion of each run.

3. Equipment subroutines which are mathematical models of equipments to be calculated. PACER as supplied by Prof. Shannon contained forty-two equipment subroutines in the PACER equipment subroutine library. The user may supply such additional equipment subroutines as he may require.

4. Data deck - the data deck describes the system or process configuration and any known stream variables or equipment parameters. It also includes certain dimension and control parameters as well as certain other operational indicators or controllers. The principal constituents of the data deck are:

(a) Process Matrix - the process matrix is the principal segment of the data deck. It describes the sytem or problem configuration and indicates stream interrelationships. Column 1 contains the equipment subroutine which performs the mathematical calculation of the equipment listed in column 1. The columns after column 2 indicate the numbers of the streams flowing into and out of equipment number listed in column 1. All input streams are listed first. All output streams must be preceded by a minus sign.

(b) Equipment Parameters Matrix - contains for each equipment listed in the process matrix a list of equipment parameters such as weight, volume, power, or heat transfer coefficient. Column 1 indicates the equipment number. All columns after column 1 contain equipment parameters for that equipment. The equipment parameters are characteristic of that equipment only.

(c) Stream Variables Matrix - contains stream variables for each stream listed in the process matrix. The stream variables represent such characteristic items as pressure, temperature, specific heat, total flow rate, component flow rates, etc. Stream variables are consistent for each stream. Column 1 contains the stream number. Column 2 is a flag indicating the status of the stream. If the flag equals 1, the stream

is a feed stream. If it equals 2, it is a product stream. If it is equal to 0, it is an internal stream. The remaining columns contain the values of the stream variables for that stream.

(d) Convergence Criteria - contains in each column an absolute fractional convergence value for each corresponding column in the stream matrix. Convergence of an item in the stream variables matrix occurs when the value calculated for that variable does not vary from the current value of that variable stored in the stream variables matrix by more than the absolute convergence criterion. The convergence criterion for a particular variable location (column) is the same for all streams.

(e) Calculation Order Listing - if provided or specified by the user it indicates the order in which the equipment will be calculated as well as the mode (direct or iterative) by which the equipments will be calculated. Column 1 indicates the equipment number and column 2 the mode of calculation. A value of 1 in the calculation mode column indicates that the equipment is to be calculated directly. A value of 2 indicates that the equipment is to be calculated iteratively. If the calculation mode is 3 the equipment is the last equipment in a list of equipment to be calculated in an iterative mode.

(f) Equipment Subroutine Listing - a listing which establishes the correspondence between the subroutine name and subroutine number to facilitate calling of proper subroutine for equipment calculations.

(g) Other control and informational parameters and data such as problem dimension parameters, problem control parameters, and title of simulation run. These items are specifically defined in Appendix A.

Chapter IV

MODIFICATIONS MADE TO PACER

Modifications Made to PACER. The PACER source deck supplied by Prof. Shannon was impressed on a 2400 foot magnetic tape at 556 bits/inch, 80 characters/record, blocked 1. With the assistance of the University of Kansas Computation Center, the magnetic tape was converted into an interpreted, punched card deck of approximately 11,500 cards.

Detailed analysis of the interpreted deck revealed that:

(1) The program was organized into eight 16K links as well as a starter link and several sample problems. The eight links were arranged as follows:

a. LINK 1 - contained mainline segment for conducting iterative calculations, calling and testing subroutines and certain equipment subroutines used in the contact sulfuric acid plant simulation.

b. LINK 3 - consisted of mainline segment which directs search for list of equipment when order of calculation is not specified, subroutines for formulation of equipment calculation list, and a subroutine for recording values calculated in direct calculations.

c. LINK 4 - composed of a mainline segment which directed input/output operations and subroutines which effected input/output operations and stream and equipment flagging.

d. LINKS 2,5,6,7,8 - contained remaining equipment and information modification and gathering subroutines used in contact sulfuric acid plant.

(2) The linking procedure employed in the program was not compatible with the GE 625 system installed at the University of Kansas.

(3) The program was written in FORTRAN II.

Further analysis indicated that the 11,500 cards could be reduced to approximately 2800 by removing all those cards pertaining to equipment subroutines used in the contact sulfuric-acid-plant simulation as well as those used in the sample problems at the end of the source deck. The cards remaining after this modification constituted

the PACER executive routine. However, it still existed in a non-compatible linked version and was written in FORTRAN II which was not permitted on the GE 625 system.

Accordingly, two additional modifications were required to make the PACER executive routine compatible with the GE 625 system. First, the program had to be converted to a linked version acceptable by the GE 625 and the program had to be rewritten in FORTRAN IV. A detailed investigation of the organization of the executive routine and the simulation model planned for development indicated that the PACER executive and the simulation model could be combined into a non-linked program which would not exceed the memory available on the 625.

The conversion from a linked to a non-linked version created several exacting problems. First, the combination of the linked main-line segments into one non-linked mainline program created a statement number redundancy. Second, it caused the invalidation of a major portion of the linked program transfer logic. This problem required extensive effort to resolve.

The rewriting of the executive routine in FORTRAN IV required considerably less effort than the conversion to a non-linked program. The major changes required were the rewriting of arithmetic function statements and input/output instructions.

Chapter V

DEVELOPMENT OF STEAM SYSTEM MODEL AND TESTING OF THE MODIFIED PACER EXECUTIVE ROUTINE

Objectives of Testing. The principal objectives of testing conducted with the modified PACER executive routine were:

(1) To verify the validity of the modifications made to the original version of PACER;

(2) To demonstrate the capability of PACER to simply and accurately simulate the performance of varying configurations of complex chemical engineering systems. In this regard it should be pointed out that specific care was taken throughout the course of the modification of PACER to insure that no alterations were made in either PACER logic or method of solution. Finally,

(3) To provide the experimental and factual basis for evaluating the potential usefulness of the modified PACER executive routine in a chemical engineering curriculum. This objective was facilitated by the steam power plant model developed by the author for testing with the modified PACER program.

Development of Simulation Model. Feasibility or validity testing of the modified PACER program presented the contrasting alternatives of (1) simulation of a segment of the contact sulfuric acid plant by use of the equipment subroutines supplied by Prof. Shannon or (2) development of a new simulation model. The second alternative was selected since it provided the opportunity for development of a more thorough understanding of PACER program logic.

The simulation model selected was that of a conventional steam power system utilizing fuel oil as its energy source. The reasons supporting this selection were:

(1) The familiarity of the author with steam power systems. This familiarity was gained by the author from service for two years as an instructor in Thermodynamics at the United States Naval Academy, as well as practical acquaintance with steam power systems as the primary means for naval ship propulsion.

(2) The general applicability of steam systems to chemical engineering.

(3) The ready adaptability of such a model to the undergraduate chemical engineering curriculum at the University of Kansas.

Accordingly, the author undertook the development of the essential equipment subroutines necessary for the approximation of a steam power system. As envisioned, the steam power system would consist of:

(1) A Turbine
(2) A Condenser
(3) A Cooling Water Circulating Pump
(4) A Condensate Pump
(5) A Heater Mixer
(6) A Feed Pump
(7) An Economizer
(8) A Boiler
(9) A Flow Splitter
(10) A Superheater
(11) A Fuel Oil Heater
(12) A Forced Draft Blower
(13) A Flow Mixer

Such a system, it was envisioned, would be amenable to demonstrating the ability of PACER to perform iterative material and energy balances by the multiple application of individual equipment subroutines.

The basic system as envisioned and developed by the author is presented in Figure 3. Figures 4 and 5 present alternate configurations of the basic system. Table 1 provides a stream legend for Figures 3-5. Figure 6 presents the process diagrams for the basic system on enthalpy--entropy coordinates. Analysis and development of mathematical models for individual components of the basic system are presented in Figures 7-19.

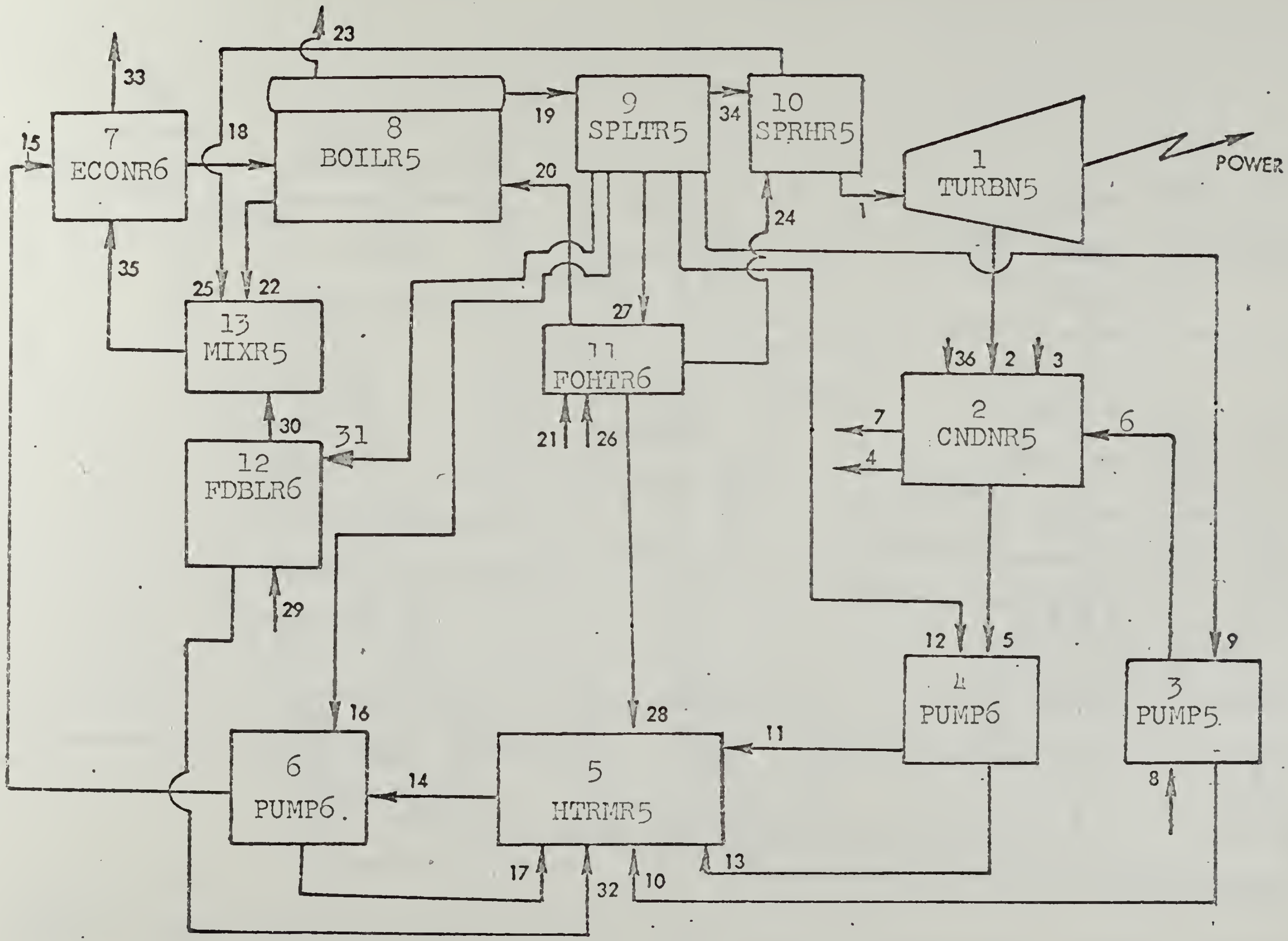


Figure 3. Flow Diagram - Runs 01 and 03, Basic Steam Power Plant System

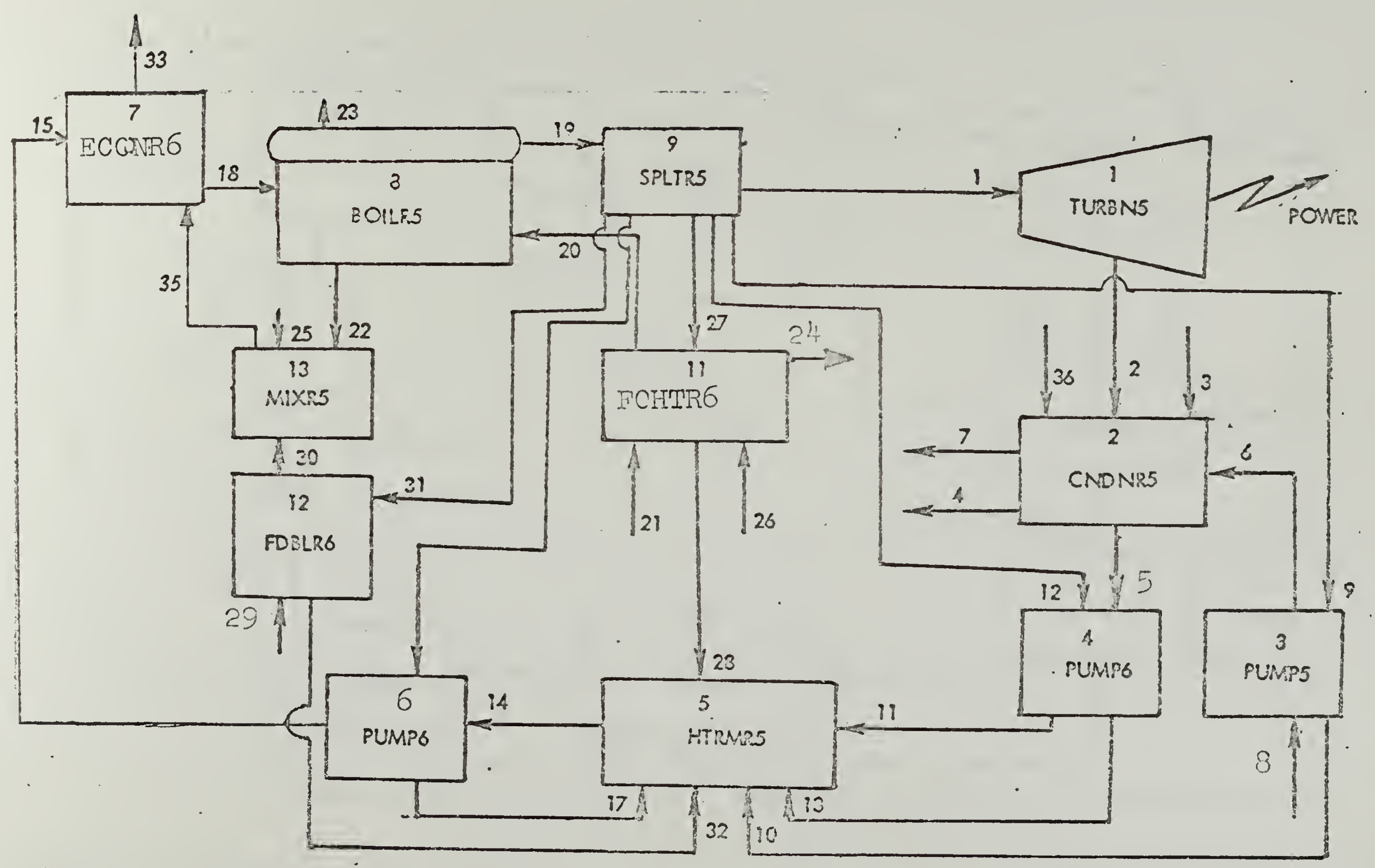


Figure 4. Flow Diagram - Run 02, Basic Steam Power Plant System Without Superheater

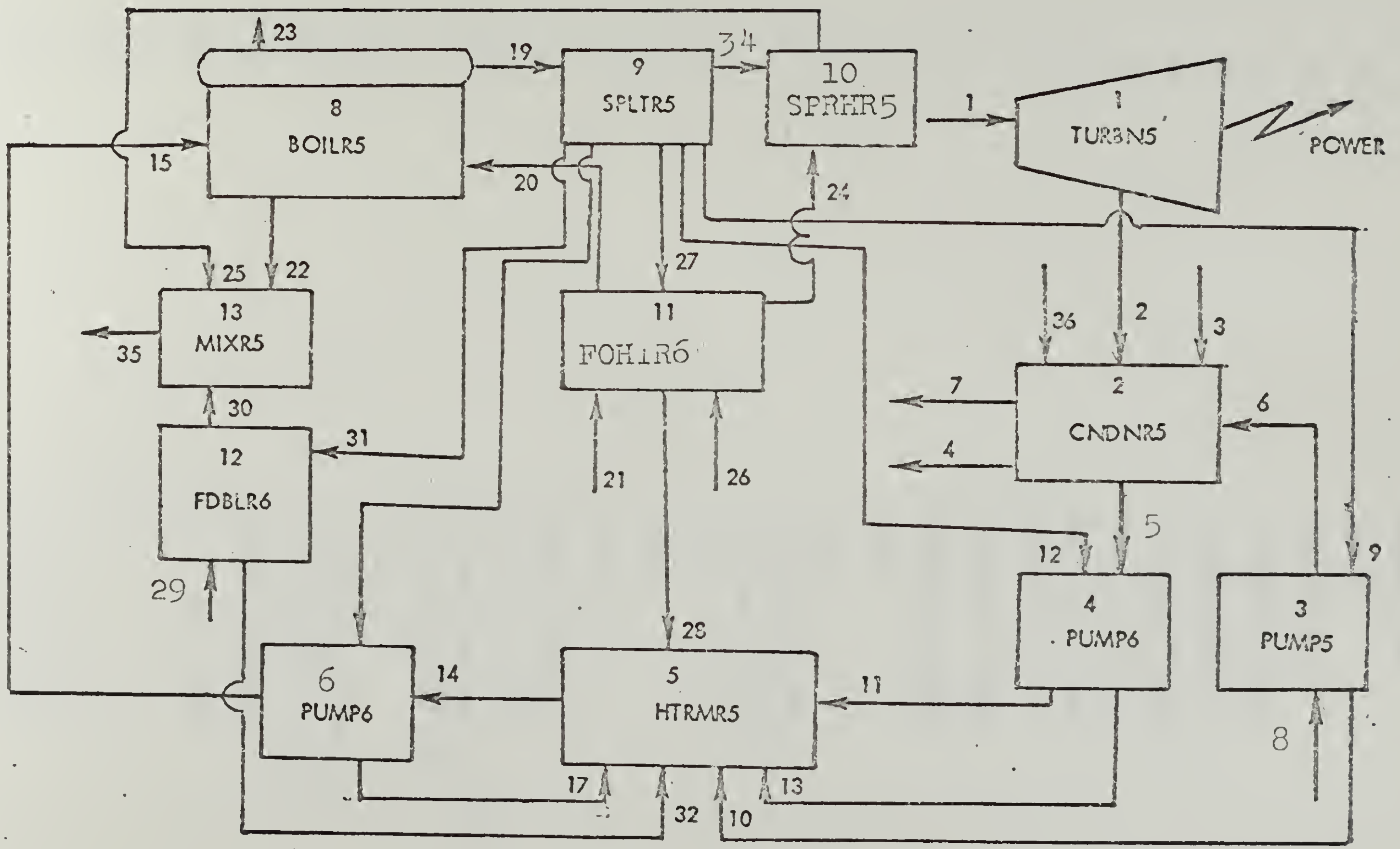


Figure 5. Flow Diagram - Run 04, Basic Steam Power Plant System Without Economizer

Stream Number	Description
1	Steam
2	Exhaust Steam
3	Impurities
4	Losses
5	Condensate
6	Cooling Water
7	Cooling Water
8	Cooling Water
9	Auxiliary Steam
10	Auxiliary Steam
11	Condensate
12	Auxiliary Steam
13	Auxiliary Steam
14	Feed
15	Feed
16	Auxiliary Steam
17	Auxiliary Steam
18	Feed
19	Steam
20	Fuel Oil
21	Boiler Fuel Oil
22	Boiler Fuel Oil
23	Boiler Blowdown of Impurities and Accompanying Feed
24	Fuel Oil
25	Superheater Fuel Oil
26	Superheater Fuel Oil
27	Auxiliary Steam
28	Auxiliary Steam
29	Air
30	Air
31	Auxiliary Steam
32	Auxiliary Steam

Table 1. Steam Power Plant Stream Legend

Stream Number	Description
33	Flue Gases
34	Steam
35	Flue Gases
36	Make-Up Feed

Table 1. (continued)

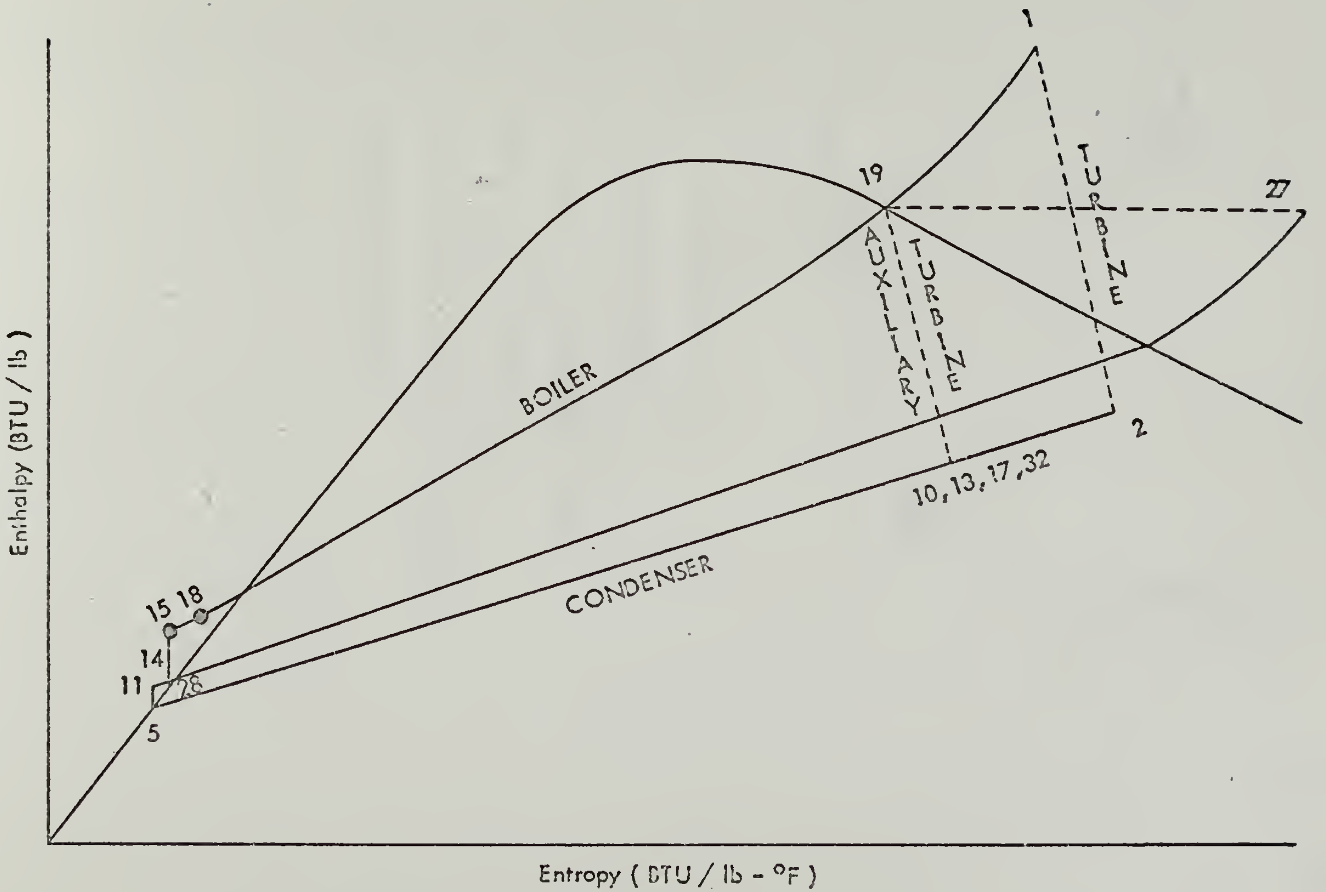
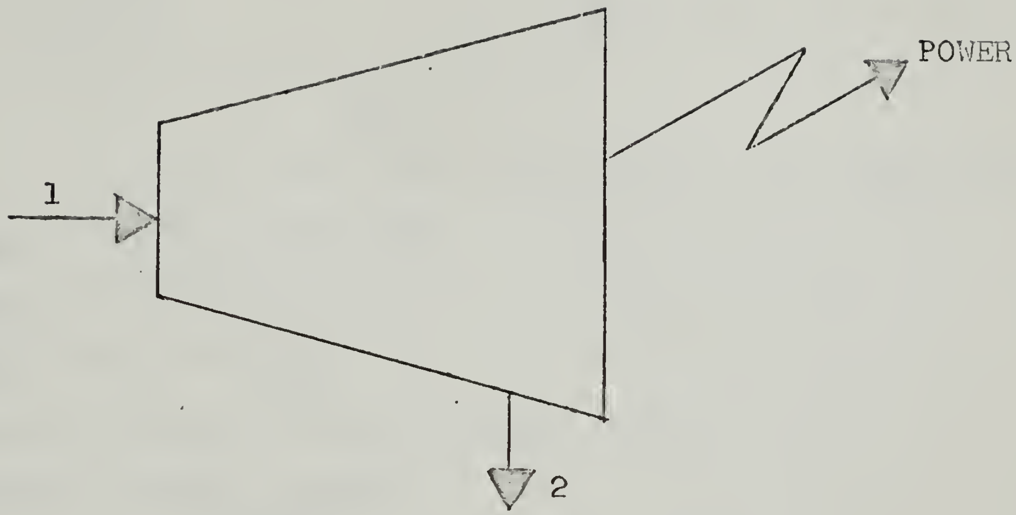


Figure 6. Process Diagram for Steam Power System



$$\text{Power} = W_{steam} \times (h_1 - h_2) \times N_m$$

$$h_2 = (h_1 - h_{1s}) \times N_{ei}$$

W_{steam} - steam flow rate

h_1 - entering enthalpy

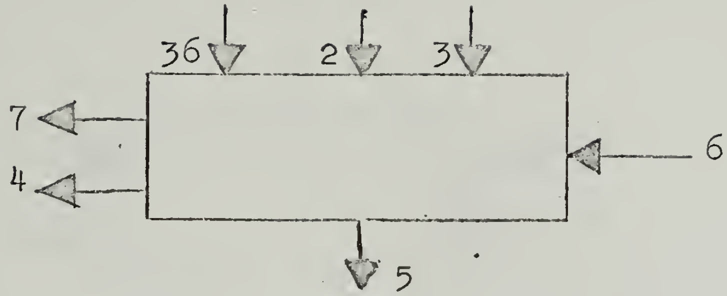
N_{ei} - internal engine efficiency

N_m - mechanical efficiency

h_{1s} - isentropic expansion enthalpy

h_2 - exhaust enthalpy

Figure 7. Turbine



$$Q = W_{steam} \times (h_2 - h_5) + W_{inpur} \times (h_3 - h_5) + W_{muf} \times (h_{36} - h_5)$$

$$W_{cw} = Q/C_{cw} \times (T_7 - T_6)$$

$$W_{inpur} = F_1 \times W_{steam}$$

$$W_{loss} = F_2 \times W_{steam}$$

$$W_{cond} = W_{steam} + W_{inpur} + W_{muf} - W_{loss}$$

$$THETAM = \frac{THETA1 - THETA2}{LN\left(\frac{THETA1}{THETA2}\right)}$$

$$AREA = Q/(U \times THETAM)$$

$$W_{muf} = W_{bdn} + W_{loss}$$

Q - heat transferred
W_{inpur} - inpurities flow rate
W_{muf} - make-up feed flow rate
T_7, T_6 - temperature
F_2 - losses flow factor
W_{bdn} - water flow rate in blowdown
W_{loss} - system losses
THETAM - log mean temperature difference
THETA1 - larger temperature difference
THETA2 - smaller temperature difference
U - overall heat transfer area
A - condenser heat transfer area
W_{steam} - steam flow rate
h_2, h_3, h_5, h_{36} - enthalpy
C_{cw} - cooling water specific heat
F_1 - inpurities flow factor
W_{cond} - condensate flow rate

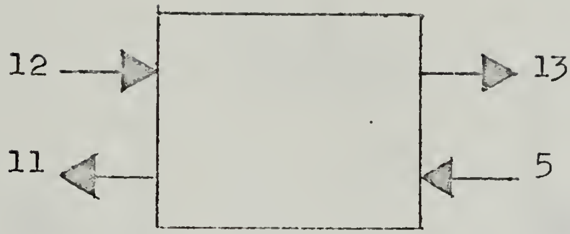
Figure 8. Condenser

$$W_{aux} = \frac{W_{fl} \times V \times (P_6 - P_8)}{(h_9 - h_{10}) \times N_m}$$

$$h_{10} = h_9 - (h_9 - h_{9s}) \times N_{ei}$$

W_{aux}	- saturated steam flow rate
W_{fl}	- pumped liquid flow rate
V	- specific volume of pumped fluid
P_6, P_8	- pressure
h_7, h_{10}	- enthalpy
h_{9s}	- isentropic expansion enthalpy
N_{ei}	- internal engine efficiency
N_m	- mechanical efficiency

Figure 9. Circulating Pump



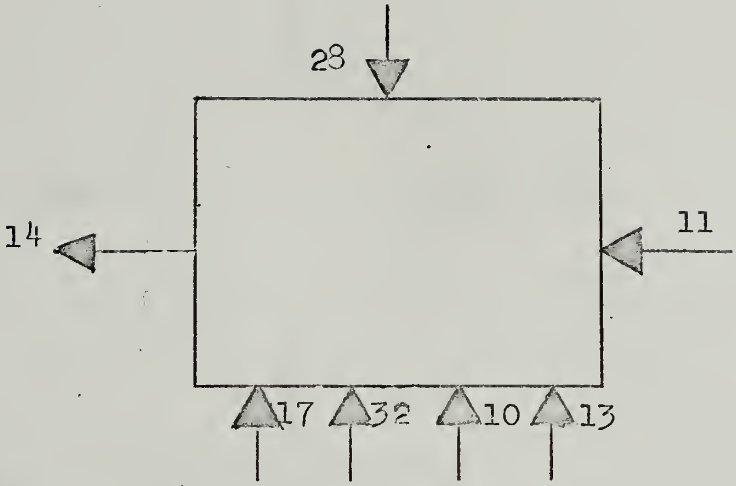
$$W_{aux} = \frac{W_{fl} \times V \times (P_{11} - P_5)}{(h_{12} - h_{13}) \times N_m}$$

$$h_{13} = h_{12} - (h_{12} - h_{12s}) \times N_{ei}$$

$$h_{11} = h_5 + V \times (P_{11} - P_5)$$

W_{aux}	- saturated steam flow
V	- specific weight of pumped fluid
P_{11}, P_5	- pressure
h_{12}, h_{13}	- enthalpy
h_{12s}	- isentropic expansion enthalpy
N_{ei}	- internal engine efficiency
N_m	- mechanical efficiency
W_{fl}	- weight rate flow of fluid being pumped

Figure 10. Condensate Pump



$$W_{fd} = W_{cond} + W_{10} + W_{13} + W_{17} + W_{28} + W_{32}$$

$$E_{in} = W_{cond} \times h_{11} + W_{10} \times h_{10} + W_{13} \times h_{13} + W_{17} \times h_{17} + W_{28} \times h_{28} + W_{32} \times h_{32}$$

$$h_{14} = E_{in}/W_{fd}$$

$$E_{sup} = W_{10} \times (h_{10} - h_{14}) + W_{13} \times (h_{13} - h_{14}) + W_{17} \times (h_{17} - h_{14}) + W_{28} \times (h_{28} - h_{14}) + W_{32} \times (h_{32} - h_{14})$$

$$T_{14} = T_{11} + E_{sup}/W_{cond} \times C_{cond}$$

W_{fd} - feed flow rate

$W_{10}, W_{13}, W_{17}, W_{28}, W_{32}$ - saturated steam flow rates

E_{in} - total energy into heater-mixer

$h_{14}, h_{11}, h_{10}, h_{13}, h_{17}, h_{28}, h_{32}$ - enthalpy

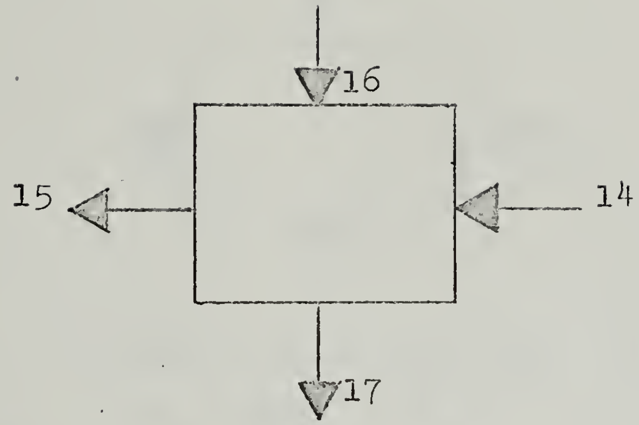
E_{sup} - energy supplied to condensate

T_{14}, T_{11} - temperature

C_{cond} - specific heat of condensate

W_{cond} - condensate flow rate

Figure 11. Heater-Mixer



$$W_{aux} = \frac{W_{fl} \times V \times (P_{15} - P_{14})}{(h_{16} - h_{17}) \times N_m}$$

$$h_{17} = h_{16} - (h_{16} - h_{16s}) \times N_{ei}$$

$$h_{16} = h_{14} + V \times (P_{15} - P_{14})$$

W_{aux} - saturated steam flow

W_{fl} - pumped liquid flow rate

V - specific volume of pumped fluid

P_{15}, P_{14} - pressure

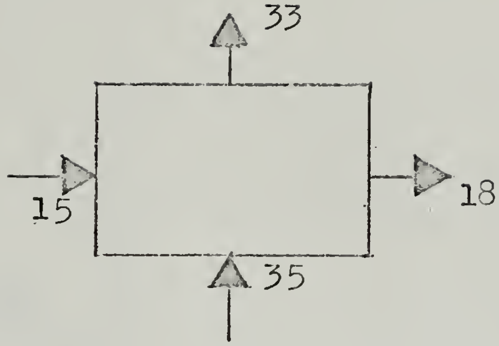
h_{16}, h_{17}, h_{14} - enthalpy

h_{16s} - isentropic expansion enthalpy

N_{ei} - internal engine efficiency

N_m - mechanical efficiency

Figure 12. Feed Pump



$$Q = W_{fd} \times C_{fd} \times (T_{18} - T_{15})$$

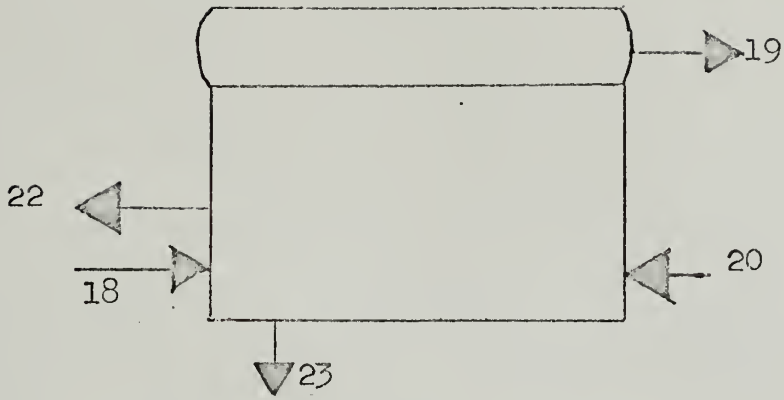
$$T_{33} = T_{35} - Q/(W_{fg} \times C_{fg})$$

$$THETAM = \frac{THETA1 - THETA2}{LN\left(\frac{THETA1}{THETA2}\right)}$$

$$AREA = Q/(U \times THETAM)$$

Q	- heat transferred
W_{fd}	- feed flow rate
C_{fd}	- specific heat of feed
T_{18}, T_{15}	- feed temperature
T_{33}, T_{35}	- flue gas temperature
W_{fg}	- flue gas flow rate
C_{fg}	- flue gas specific heat
THETAM	- log mean temperature difference
THETA1	- larger temperature difference
THETA2	- smaller temperature difference
U	- overall heat transfer coefficient
AREA	- economizer heat transfer area

Figure 13. Economizer



$$HV = 14600 \times C + 62000 \times (H - O_2/8) + 4000 \times S$$

$$W_{tbdn} = (W_{inpur} \times F_3) + W_{inpur}$$

$$W_{bdn} = F_3 \times W_{inpur}$$

$$W_{sat} = W_{fd} - W_{tbdn}$$

$$Q = W_{fd} \times (h_{sl} - h_{18}) + W_{sat} \times (h_{19} - h_{sl})$$

$$W_{fol} = Q/(HV \times N_b)$$

HV - heating value of fuel oil[24]

C,H,O,S - carbon, hydrogen, oxygen and sulfur weight fractions in fuel oil

W_{tbdn} - total boiler blowdown

W_{inpur} - inpurities flow rate

F_3 - inpurities blowdown factor

W_{bdn} - pure water in blowdown

W_{sat} - saturated steam

Q - heat transferred

h_{sl} - enthalpy of saturated liquid

h_{18}, h_{19} - enthalpy

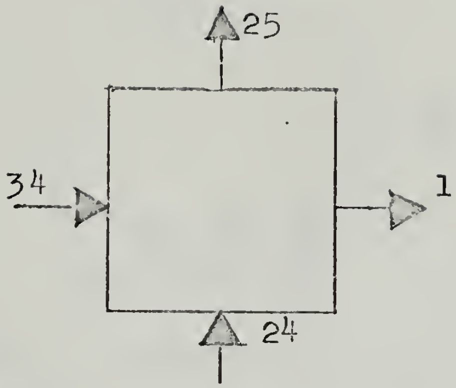
W_{fol} - fuel oil flow rate

N_b - boiler efficiency

Figure 14. Boiler

No mathemaical calculations take place in the splitter. The splitter merely serves as a convenient manner for splitting the saturated steam flow produced in the boiler into its various components without needlessly encumbering the boiler calculations.

Figure 15. Splitter



$$Q = W_{steam} \times (h_1 - h_{34})$$

$$HV = 14600 \times C + 62000 \times (H - O_2/8) + 4000 \times S$$

$$W_{fo2} = Q/(HV \times N_b)$$

Q - heat transferred

h_1, h_{34} - enthalpy

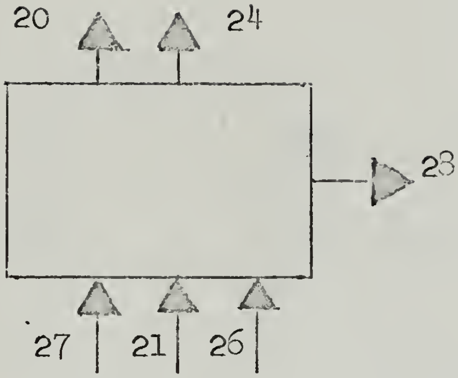
HV - heating value of fuel oil[25]

C, H, O_2, S - carbon, hydrogen, oxygen and sulfur weight fractions in fuel oil

W_{fo2} - fuel oil flow rate

N_b - boiler efficiency

Figure 16. Superheater



$$Q = (W_{fo1} + W_{fo2}) \times C_{fo} \times (t_{24} - t_{26})$$

$$W_{aux} = Q/(h_{27} - h_{28})$$

Q - heat transferred

W_{fo1} - fuel oil flow rate to boiler

W_{fo2} - fuel oil flow rate to superheater

C_{fo} - specific heat of fuel oil

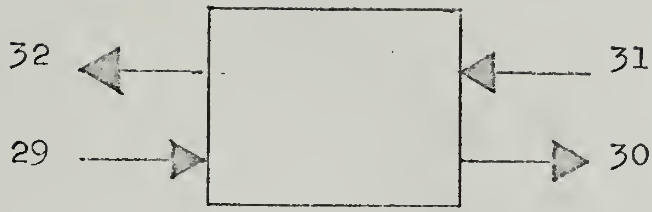
$t_{24}(=t_{20})$ - fuel oil exit temperature for proper atomization[26]

$t_{21}(=t_{26})$ - fuel oil entrance temperature

W_{aux} - saturated steam flow rate

h_{27}, h_{28} - enthalpy

Figure 17. Fuel Oil Heater



$$A/F = \frac{XA \times C_1 \times 44 + XA \times C_2 \times 3.78 \times 28}{C_3 \times FO}$$

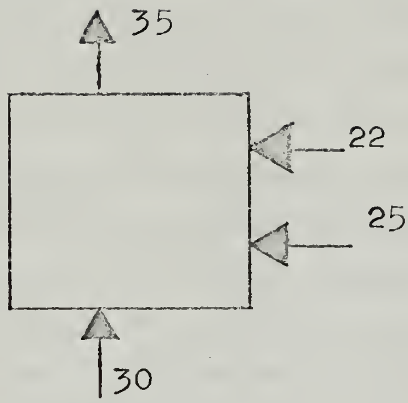
$$W_{air} = (W_{fo1} + W_{fo2}) \times A/F$$

$$W_{aux} = \frac{W_{air} \times V^2}{2gJ \times (h_{31} - h_{32})\ N_m}$$

$$h_{32} = h_{31} - (h_{31} - h_{31s})\ N_{ei}$$

A/F	- air-fuel ratio
XA	- percent excess air
C_1	- stoichiometric coefficient for oxygen
C_2	- stoichiometric coefficient for nitrogen
C_3	- stoichiometric coefficient for fuel oil
FO	- molecular weight of fuel oil
W_{air}	- air flow rate
W_{fo1}, W_{fo2}	- fuel oil flow rates
W_{aux}	- saturated steam flow rate
V	- velocity
g	- acceleration due to gravity
J	- Joules constant
h_{31}, h_{32}	- enthalpy
h_{31s}	- isentropic expansion enthalpy
N_m	- mechanical efficiency
N_{ei}	- internal engine efficiency

Figure 18. Forced Draft Blower



$$W_{fg} = W_{22} + W_{25} + W_{30}$$

W_{fg} - flue gases flow rate

W_{22}, W_{25} - fuel oil flow rates

W_{30} - air flow rate

Figure 19. Mixer

Plan of Testing. The development of a series of approximations to achieve the objectives established above required a systematic analysis to determine if any of the objectives were complementary or interdependent, and, if so, in what manner and in what order.

An analysis of these relationships revealed that the objective of verifying the validity of the modifications made to PACER was the objective on which all the other objectives depended. Additionally, it was concluded that objectives two and three could be achieved as derivatives of objective one. That is, if simulation tests could be developed which would establish the validity of the modifications and the accuracy of the model, then the efficacy of PACER and the model and their usefulness in chemical engineering education could be determined by derivation from those results.

Accordingly, a series of six simulations were scheduled for testing with the modified PACER program. The first, Run 01, was designed to approximate the performance of the basic system with the order of calculations specified by the user. The second simulation, designated Run 03, involved the same basic system but did not specify the order of calculations. The accuracy of the solutions was not of primary concern in these tests. Rather, the objective was to ascertain if the modified program were processing the data in accordance with the methods described in the documentation provided by Prof. Shannon and inferred from an analysis of the original PACER.

Two additional system configurations were tested to demonstrate the ability of PACER to provide accurate solutions of varying configurations of the same system. The first of the altered configurations, labeled Run 02, involved all the components of the basic system except the superheater. The second altered configuration consisted of the basic system less the economizer. This run was designated Run 04. Both Runs 02 and 04 were run with the order of calculation specified and unspecified. The results obtained from these runs were compared with hand-calculated values and corrections as necessary, and were made in the models until the computed values agreed with the hand calcuations for all cases.

The final results of all runs are presented in Appendix B, with extensive diagnostic print-out (a PACER option) provided for Runs 01 and

03. A guide for the interpretation of the results of the simulations accompanies the results in Appendix B.

Chapter VI

ANALYSIS OF TEST RESULTS

Accuracy of Results. Acceptable limits of accuracy vary with the nature of the problem being evaluated. Quite clearly, the acceptable limits of accuracy in determining the configuration of the critical mass of a fissionable material would be much more rigorous than those to be imposed on the sytem parameters and configuration of a steam power plant. In the latter case, slide rule accuracy is normally acceptable. Accordingly, a convergence criterion of .02 (2%)--an approximation of slide rule accuracy--was selected for all steam variables other than those non-varying items such as stream number and flag value. With this criterion, all runs converged to solution in no more than five iterations.

The values of stream variable calculated by PACER were compared to hand-calculated values and in all cases were within slide rule accuracy of hand-calculated values.

Effect of Specifying Order of Calculations. PACER undertakes trial and error (iterative) solutions in all cases where the order of calculations is not specified or where an iterative calculation is specified. Under these conditons, the advantage of specifying the order of equipment calculations was not clear. In Run 02 (without superheating) both the calculations with and without the order of calculations specified converged in five loops. In Run 04 (without economizer) the calculations with the order of calculations specified converged in three iterative loops, whereas the calculations without the order of calculations specified converged in four loops. Runs 01 and 03 (basic system) converged in five and four loops respectively.

The inconclusive nature of these results would seem to indicate that the PACER method of determination of order of calculation is as effective in promoting convergence as intuitive designation of the order of calculation--or at least no more ineffective.

Another aspect of this consideration is the comparison of the values of stream variables obtained with different orders of calculations. Quite clearly convergence values will be expected to vary depending on the

logical location of equipment in the order of calculations. While this expectation was confirmed, differences were in all cases less than the convergence criterion.

Effects of Changes in System Configuration. Two major changes to the basic steam power system were simulated with the modified PACER program. The first change involved removal of the superheater from the basic system. This change necessitated the use of saturated steam in the turbine with the result that for the same turbine power requirement, steam flow increased 12%. However, fuel oil flow increased only 1%. Condenser surface area increased 6%.

The second change involved removal of the economizer from the steam power system. This change necessitated the addition of the heat that would have been added by flue gases in the economizer as the heat of combustion of additional fuel oil. This change resulted in a 20% increase in fuel oil flow.

Realism of the Models. The qualitative and quantitative nature of the stream variables tended in all cases to verify the realistic nature of the models developed by the author. For example, the use of saturated steam in lieu of superheated steam would undoubtedly require more steam to produce the same turbine power. The greater steam flow would normally require more fuel oil. However, the fact that the additional steam was saturated and the original superheating load was no longer required had an offsetting effect on fuel oil flow.

Additionally, as was demonstrated in Run 04, the loss of the regenerative heating affect of the economizer would quite clearly require more fuel oil for the same power requirement.

While these results tend to verify the realistic nature of the steam power system developed by the author, it should be understood that no attempt was made in the development of the model to completely depict reality. Rather an attempt was made to provide a semi-realistic model which could be refined subsequently. It should be noted in this regard that most of the data and mathematical bases for equipment and sytems models are based on reliable data developed from many years in the design, development and operation of naval steam power plants.

Validity of Modifications Made to PACER. The close conformance of the values obtained in the simulations with hand-calculated values, as well as the general and specific correspondence of results to format and arrangement of data as described in documentation provided by Prof. Shannon clearly establishes the validity of modifications to the original PACER program.

Chapter VII

AN ASSESSMENT OF PACER

General. The author has demonstrated the concept, principles and method of application of the PACER simulation program by the development of a complex model of a steam power system, and successfully approximating its performance on a modified version of the original PACER. The validity of the modifications made to PACER have been conclusively established by the accuracy of the results achieved. The realistic nature of the model has been tentatively established by the qualitative and quantitative nature of the results.

PACER As A Simulation Device. PACER has been demonstrated to be a powerful, flexible and efficient method for simulation of complex configurations of chemical engineering systems.

However, certain areas where improvements in PACER method of operations or concept could be made were noted and are discussed here for edification of potential users.

(1) The addition or removal of equipment subroutines from PACER is cumbersome with present arrangement of calling segments and subroutines and LPHA listing. A more permanent, non-mnenonic name for equipment subroutines requiring only a change in subroutine name to conform to permanently established but unused name is one method of alleviating this problem. This would obviate changes in mainline program which become more difficult when executive program is on tape.

(2) Consideration should be given to establishment of permanent STRMI and STRMO matrices to accommodate all streams on a permanent basis for a run. This would facilitate multiple calling of stream variable and information transmittal in a particular run. However, it could develop that the ultimate result would be to trade the present inflexibility of a temporary STRMI and STRMO matrix for an inflexible permanent matrix.

(3) Consideration should be made for incorporating capital investment costs into equipment subroutines. This information could take the form of a cost which varies with heat transfer area, pressure, temperature, etc. Incorporation of this data into the basic structure of an equipment

subroutine is a relatively simple matter--primarily a function of availability of cost information and its relationship to design or operating parameters.

Use of PACER In A Chemical Engineering Curriculum. In evaluating the results of the simulation of the C-I-L contact sulfuric acid plant using the PACER program, Prof. Shannon remarked:

> It should be emphasized that this study, although it involved a unique and very close cooperation with industry, was in the main an exercise in the education of engineering students. The students were concerned with the detailed modelling of specific equipment, yet had a very broad exposure to a real industrial plant and its over-all behavior. They learned of the difficulties and importance of obtaining good plant data, and of writing successful programs of greater complexity than previously encountered. The project was admittedly a very ambitious one; however the large effort expended has placed PACER into the hands of the staff for future use in the undergraduate and graduate program.
>
> The staff generally agree that most of the students have benefitted by this exposure to the quite new concept of information handling and decision making utilizing PACER.[27]

PACER then has already demonstrated its effectiveness in instilling in students some aspects of "engineering experience" which would not normally be obtainable outside an industrial environment. This, as stated in the University of Michigan Report on the uses of computers in engineering education, is the raison d'etre of engineering design courses.[28]

It is further considered that PACER can be an effective means of developing a systematic approach to problem solving by chemical engineering students. The demands of computer programming in development of equipment subroutines and systems concepts requires strict attention to problem structuring and formulation.

Recommmendations. In consideration of the results of the simulations conducted with the modified PACER program and the conclusions drawn above, it is recommended that:

(1) Consideration be given to the incorporation of the modified PACER program into existing undergraduate courses involving basic problems in chemical engineering. The steam power system as developed by

the author is amenable to immediate use on an individual or term project basis, and

(2) After suitable evaluation of the effectiveness of the initial use of PACER that consideration be given to further and more extensive use of PACER in graduate and research projects at the University of Kansas.

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Appendix A

USER'S GUIDE FOR THE MODIFIED PACER SIMULATION PROGRAM

General. The most significant feature of the PACER simulation method is its ability to perform realistic and accurate simulations of varying configurations of complex chemical engineering systems with a minimal effort on the part of the user. The element of PACER which makes this capability possible is a highly-structured data deck which permits the user to fully characterize system configuration and the restraints or parameters under which it operates.

Successful use of PACER is dependent upon strict adherence to a prescribed set of instructions for the formulation, assembly and modification of the data deck. It is the purpose of this appendix to provide the necessary instructions in a manner which will permit a user to employ PACER's powerful calculational skills without having to master either the logic or structure of PACER. One exception exists to this condition. That occurs when it is necessary to develop or modify equipment subroutines or add them to or delete them from the program. In that case a minimal knowledge of the structure and logic of PACER is required to insure the subroutines conform to PACER logic and that they are properly entered into PACER structure. Both of these aspects will be treated in this appendix.

System Conceptualization. The initial step in preparing a system configuration for simulation by PACER is to establish the system concept and commit the concept to formalization by preparation of a flow diagram. This flow diagram should break equipment assemblies into subassemblies and equipments capable of being mathematically modelled. For example, a boiler normally contains an economizer and a superheater as integral equipments, and when one normally refers to a boiler it is assumed that he includes the economizer and superheater if they are provided. However, breaking these elements out and handling them as separate equipments facilitates mathematical and system modelling as well as increasing the flexibility of the model. Further, the functional components if of sufficient general nature could be used in multiple applications within a single simulation or as a related equipment in subsequent simulations.

In developing the system flow diagram all equipments, the performance of which will be simulated by mathematical models (equipment subroutines), should be numbered. No redundancy in equipment numbering is permitted although equipment numbers need not be successive. While equipments are being numbered, they should also by named. For convenience it would be preferable to assign them a six-character alphanumeric name which is mnemonically related to the equipment function, e. g. TURBN5 for turbine and CNDNR5 for condenser. No redundancy is permitted in the last 3 characters of a unit name, although individual characters within a unit name may be repeated. For example, TURBN5 and TURBN6 are acceptable, while SPLTR5 and SPHTR5 are not.

After all equipments have been numbered and named, all interconnecting streams should be numbered. No redundancy is permitted in stream numbers. However, stream numbers need not be successive nor is redundancy between stream and equipment numbers prohibited.

Equipment Subroutine Format. The equipment subroutine is the one facet of PACER that poses a programming burden on the user. If an equipment subroutine which satisfies the analytical and calculational requirements of an equipment which is to be simulated is not available in the PACER subroutine library, the user must develop an equipment subroutine which accomplishes these objectives.

Several challenges confront the user developing an equipment subroutine for use in a PACER simulation. The first challenge is to insure that the equipment to be modelled is, in fact, the equipment which should be modelled. In this respect a general effort should be made to break equipment assemblies down into their functional elements, that is, as previously mentioned, a boiler into a boiler, an economizer and a superheater. Mathematical analysis is facilitated and simplified by this approach. Further, specific effort should be directed toward incorporating generality into subroutines. That is, an economizer is in essence a two-fluid heat exchanger. If the equipment subroutine can be written for a general two-fluid heat exchanger which is in this application called an economizer, then the equipment subroutine can be used in subsequent future applications where a two-fluid heat exchanger is employed. The fact of this generality should be documented into the subroutine by appropriate comments.

Once the mathematical representation of an equipment has been developed it is necessary to translate this into the syntax employed by PACER. This task can be mastered quickly by knowledge of a few basic concepts of PACER.

PACER performs equipment calculations by using mathematical relationships provided by the user in the equipment subroutine and stream and equipment data provided by the user in the stream (SN) and equipment (EN) matrices of the data deck (to be discussed further in section dealing with the data deck). PACER calls data out of the stream matrix into temporary STRMI (inlet streams) and STRMO (outlet streams) for the equipment to be calculated. The inlet and outlet streams for a particular equipment are designated by the user in the process matrix (KPM). Stream variable information is then ready for use in PACER calculations. Equipment parameters are called from and returned directly to the EN matrix for the equipment to be calculated. Once the equipment has been calculated the values in the STRMI and STRMO matrices are returned to permanent storage in the SN matrix. The STRMI and STRMO matrices are then available for temporary storage of inlet and outlet stream variables for next equipment to be calculated.

It is then incumbent upon the user to transcribe his mathematical notation into a notation which indicates to PACER where in the STRMI, STRMO or EN matrices the variable or parameter to be used is to be located. For example, let us convert the mathematical equation for determining turbine stream flow rate into a notation usable by PACER. The equation (neglecting dimensional constants) is:

$$W = P \div Wk$$

In FORTRAN this is represented as

```
W = P/WK
```

However, in PACER notation it would be written as

```
STRMI (1,10) = EN (NE,3) / (STRMI(1,5) - STRMO(1,5))
        (where WK = (STRMI(1,5) - STRMO(1,5)))
```

In the above notation

STRMI(1,10) - indicates the tenth variable in the first inlet stream to the equipment being calculated. It also represents the tenth

variable in the stream matrix vector for the stream which is the first input stream to the equipment. In the context of this sample, this variable represents the stream flow for that stream.

EN (NE,3) - indicates the third parameter for equipment NE. Equipment NE is the equipment number for the equipment being calculated and will be set elsewhere in PACER. The turbine power rating for equipment NE will be stored in this location.

STRMI (1,5) and STRMO (1,5) - represent the fifth variable in the first inlet and outlet streams respectively. In this example these variables take on the value of the entering and leaving enthalpies of the first inlet and outlet streams to equipment NE.

The effect of the above calculation is to calculate a value for steam flow for the stream number which is the first inlet stream to equipment NE. After calculation this calculated value is stored in the SN matrix releasing the STRMI and STRMO matrices available for further calculations. Since the values of EN(NE,3) and STRMI(1,5) and STRMO (1,5) were not modified, the corresponding values in the EN and SN matrices will not be modified.

Figures A1. and A2. are the equipment subroutines for the mathematical models developed for the turbine and condenser in Chapter 4 (See Figures 7 and 8). It should be pointed out that the assignment of variable and parameter locations in the SN, EN, STRMI and STRMO matrices are the responsibility of the user. Further, stream variable location must be consistent for all streams in the SN, STRMI and STRMO matrices. That is location 5 in the SN, STRMI and STRMO matrices will throughout the course of a run represent the same variable, but not necessarily the same value. For example, in the illustrative example discussed above, location 5 represented the enthalpy for all streams but the enthalpy for all streams was not necessarily the same value and some streams did not even store a value for enthalpy if it were not relevant to the calculation of that equipment. In such a case PACER normally assigns a value of zero to that location.

One additional note of caution is that a common and dimension deck identical to that used in the mainline program must be the first item

```
      SUBROUTINE TURBN5
C
C*****PAGER COMMON AND DIMENSION DECK
      DIMENSION STRMI(8,15),STRMCI(5,5),STRMO(8,15),STRMCO(5,5),
     1SN(50,15),SNC(50,5),EN(30,15),ENC(30,5),NECALL(50),NAME(30),
     2NAME2(30),NAME3(30),NAME4(30),KE1(30),KSEM(50,3),KUS(50),KPS(6),
     3DELS(15),DELSC(5),KPM(30,9),KEFLAG(30),KSFLAG(50),TITLE(24),
     4LPHA(30),KOMPNO(10),AEN(4,40),NELIST(30,2),KSPRNT(16),PAPER(4,15),
     5NPAPER(20)
      COMMON  STRMI, STRMCI, NIN,         STRMO, STRMCO, NOUT
      COMMON  SN,NSLMAX, SNC, NSCLMX, DELS, DELSC,KSEM
      COMMON  NELMAX, ENC, NECLMX
      COMMON  KEFLAG, NEMAX, KSFLAG, NSMAX, NECALL, NEQUIP
      COMMON  KPM, N2MAX, N3MAX, TITLE
      COMMON  AEN, LPHA, KOMPNO, NOCOMP, NELIST
      COMMON  NAME, NAME2, NAME3, NAME4, KRET, KRET2, KRET3, NOAEN, NOEN
      COMMON  LIMIT, LIMIT2, LOOP, KBACK, KBACK2, KVOID
      COMMON  KRUN, KSETS, KCLEAN, LOOPS, NOGO, KARDS, KPRINT, KONV
      COMMON  MCHAIN, NCHAIN, KLOCK1
      COMMON  KOUNT1, KOUNT2, KOUNT3, KOUNT4, KOUNT5
      COMMON  EN, NE, NLIST, LIST
      COMMON  KUS,NUSMAX,    KPS, NPS
      COMMON  NUS1, NUS2, NUS3,             KCV1, KCV2, KCV3
      COMMON  NSUSED,NEUSED,KSPRNT,PAPER,NPAPER,NEXT
      COMMON  KE1,NE1MAX,WFUEL1,WFUEL2,IXRAY,JXRAY,WBDN
C
C*****SUBROUTINE TURBN5 CALCULATES THE STEAM FLOW REQUIRED TO PRODUCE A GIVEN
C     TURBINE POWER OUTPUT, USE IS MADE OF THE RELATIONSHIP THAT FOR A
C     STEAM TURBINE POWER = STEAM FLOW X TURBINE WORK, WHERE TURBINE WORK
C     IS MANIFESTED AS THE PRODUCT OF THE CHANGE IN ENTHALPY OF THE STEAM
C     IN THE TURBINE AND THE TURBINE MECHANICAL EFFICENCY,
C
C     NOMENCLATURE
C        STRMO(1,5) - OUTLET STEAM ENTHALPY(BTU/LB)
C        STRMI(1,5) - INLET STEAM ENTHALPY(BTU/LB)
C        EN(NE,5) - INTERNAL ENGINE EFFICIENCY(PERCENT)
C        EN(NE,6) - MECHANICAL EFFICIENCY(PERCENT)
C        EN(NE,4) - ISENTROPIC STEAM EXHAUST ENTHALPY(BTU/LB)
C
C*****CALCULATE OUTLET STEAM ENTHALPY
      STRMO(1,5)=STRMI(1,5)-(STRMI(1,5)-EN(NE,4))*(EN(NE,5)/100.)
C*****CALCULATE STEAM FLOW
      STRMI(1,8)=(EN(NE,3)*2545000.)/(EN(NE,6)*EN(NE,5)*(STRMI(1,5)-
     1EN(NE,4)))
      STRMI(1,10)=STRMI(1,8)
      STRMO(1,8)=STRMI(1,8)
      STRMO(1,10)=STRMO(1,8)
      STRMO(1,9)=0.
      STRMI(1,9)=STRMO(1,9)
      DO 10 J=11,15
      STRMO(1,J)=0.
      STRMI(1,J)=STRMO(1,J)
   10 CONTINUE
      DO 20 I=6,7
      STRMO(1,I)=0.
      STRMI(1,I)=STRMO(1,I)
   20 CONTINUE
C*****IF MCHAIN = 3, EQUIPMENT IS BEING CALCULATED DIRECTLY
      IF(MCHAIN-3) 1000,1001,1000
 1000 IXRAY=0
      GO TO 1002
 1001 IXRAY=3
 1002 RETURN
      END
```

Figure A1. Subroutine TURBN5

```
      SUBROUTINE CNDNR5
C
C*****PACER COMMON AND DIMENSION DECK
      DIMENSION STRMI(8,15),STRMCI(5,5),STRMO(8,15),STRMCO(5,5),
     1SN(50,15),SNC(50,5),EN(30,15),ENC(30,5),NECALL(50),NAME(30),
     2NAME2(30),NAME3(30),NAME4(30),KE1(30),KSEM(50,3),KUS(50),KPS(6),
     3DELS(15),DELSC(5),KPM(30,9),KEFLAG(30),KSFLAG(50),TITLE(24),
     4LPHA(30),KOMPNO(10),AEN(4,40),NELIST(30,2),KSPRNT(16),PAPER(4,15),
     5NPAPER(20)
      COMMON  STRMI, STRMCI, NIN,        STRMO, STRMCO, NOUT
      COMMON  SN,NSLMAX, SNC, NSCLMX, DELS, DELSC,KSEM
      COMMON  NELMAX, ENC, NECLMX
      COMMON  KEFLAG, NEMAX, KSFLAG, NSMAX, NECALL, NEQUIP
      COMMON  KPM, N2MAX, N3MAX, TITLE
      COMMON  AEN, LPHA, KOMPNO, NOCOMP, NELIST
      COMMON  NAME, NAME2, NAME3, NAME4, KRET, KRET2, KRET3, NOAEN, NOEN
      COMMON  LIMIT, LIMIT2, LOOP, KBACK, KBACK2, KVOID
      COMMON  KRUN, KSETS, KCLEAN, LOOPS, NOGO, KARDS, KPRINT, KONV
      COMMON  MCHAIN, NCHAIN, KLOCK1
      COMMON  KOUNT1, KOUNT2, KOUNT3, KOUNT4, KOUNT5
      COMMON  EN, NE, NLIST, LIST
      COMMON  KUS,NUSMAX,     KPS, NPS
      COMMON  NUS1, NUS2, NUS3,           KCV1, KCV2, KCV3
      COMMON  NSUSED,NEUSED,KSPRNT,PAPER,NPAPER,NEXT
      COMMON  KE1,NE1MAX,WFUEL1,WFUEL2,IXRAY,JXRAY,WBDN
C
C*****SUBROUTINE CNDNR5 DETERMINES THE COOLING WATER FLOW RATE AND THE SUR-
C     FACE AREA REQUIRED TO CONDENSE THE EXHAUST STEAM FROM THE TURBINE.
C     IT ALSO CALCULATES THE FLOW RATE OF IMPURITIES INTRODUCED INTO THE
C     SYSTEM AND THE STEAM AND WATER LOSSES BY LEAKAGE, EVAPORATION, ETC.
C     THE CONDENSER SURFACE AREA IS CALCULATED FROM THE RELATIONSHIP THAT
C     Q = U X A X THETAM, WHERE U IS THE OVERALL HEAT TRANSFER COEFFICIENT
C     AND THETAM IS THE LOG MEAN TEMPERATURE DIFFERENCE.
C
C     NOMENCLATURE
C         STRMO(1,8) - LOSSES(LB/HR)
C         STRMI(1,8) - TURBINE EXHAUST STEAM(LB/HR)
C         EN(NE,4) - FACTOR FOR DTERMINING LOSSES(LB LOSSES/LB STEAM)
C         STRMI(2,8) - IMPURITIES(LB/HR)
C         EN(NE,3) - FACTOR FOR DETERMINING IMPURITIES(LB IMPURITIES/LB STEAM)
C         STRMI(4,8) - MAKE-UP FEED(LB/HR). EQUALS LOSSES + BLOWDOWN FLOW RATE.
C         STRMI(3,8) - COOLING WATER FLOW RATE(LB/HR)
C
      IF(LOOP.EQ.1) GO TO 77
      GO TO 78
   77 WBDN=0.
   78 CONTINUE
C*****CALCULATE LOSSES
      STRMO(1,8)=STRMI(1,8)*EN(NE,4)
      STRMO(1,10)=STRMO(1,8)
C*****CALCULATE IMPURITIES
      STRMI(2,8)=EN(NE,3)*STRMI(1,8)
      STRMO(2,11)=STRMI(2,8)
      STRMI(1,10)=STRMI(1,8)
      STRMI(2,11)=STRMI(2,8)
C*****CALCULATE MAKE-UP FEED
      STRMI(4,8)=STRMO(1,8)+WBDN
      STRMI(4,9)=STRMI(4,8)
C*****CALCULATE HEAT TRANSFERRED
      Q=(STRMI(1,8)-STRMO(1,8))*(STRMI(1,5)-STRMO(2,5))+STRMI(2,8)*
     1(STRMI(2,5)-STRMO(2,5))+STRMI(4,8)*(STRMI(4,5)-STRMO(2,5))
C*****CALCULATE COOLING WATER FLOW
      STRMI(3,8)=Q/(EN(NE,5)*(STRMO(3,4)-STRMI(3,4)))
      STRMO(3,8)=STRMI(3,8)
      STRMI(3,15)=STRMI(3,8)
      STRMO(3,15)=STRMO(3,8)
```

Figure A2. Subroutine CNDNR5

```
C*****CALCULATE LOG MEAN TEMPERATURE DIFFERENCE
      THETA1=STRMI(1,4)-STRMI(3,4)
      THETA2=STRMI(1,4)-STRMO(3,4)
      THETAM=(THETA1-THETA2)/ALOG(THETA1/THETA2)
C*****CALCULATE HEAT TRANSFER AREA
      AREA1=Q/(EN(NE,6)*THETAM)
      WRITE(6,814 ) AREA1
  814 FORMAT (//35H CONDENSER SURFACE AREA REQUIRED = F10.2,7HSQ. FT.)
C*****CALCULATE CONDENSATE FLOW
      STRMO(2,8)=STRMI(1,8)+STRMI(2,8)-STRMO(1,8)+STRMI(4,8)
      STRMO(2,9)=STRMO(2,8)-STRMO(2,11)
C*****IF MCHAIN = 3, EQUIPMENT IS BEING CALCULATED DIRECTLY
      IF (MCHAIN-3) 1000,1001,1000
 1000 IXRAY=0
      GO TO 1002
 1001 IXRAY=3
 1002 RETURN
      END
```

Figure A2. Contd.

in each subroutine. This facilitates communication of information from subroutines to mainline and other subroutines.

Incorporation or Removal of Equipment Subroutines into PACER Structure. The flexible nature of PACER permits the incorporation or removal of equipment subroutines to conform to core memory limitations, to permit the simulation of completely different systems or to permit modification of existing systems. Such flexibility is not achieved, however, without a commensurate demand on the user. In this case, it is the requirement that the incorporation or removal of a subroutine requires a change in the semi-permanent structure of PACER.

Each subroutine, in addition to being assigned a six-character, alpha-numeric title, is assigned an equipment subroutine number depending on the location of its calling statement in PACER. Equipment subroutines 1-10 are called from EQCAL and subroutines 11-30 are called from the mainline program. The location of these calling statements and maximum number of subroutines are a function of the system to be simulated. However, a note of caution. An increase or decrease in the maximum number of equipment subroutines or any other dimension establishing parameter requires a change in the appropriate matrix or vector in the common and dimension deck.

The incorporation of a subroutine requires

(1) Obtaining an equipment subroutine number from those not currently being used.

(2) Writing a calling statement for that subroutine.

(3) Providing appropriate transfer directions or transfer indicators.

For example, the addition of an equipment subroutine COOLR8 as subroutine number 5 would require the insertion of the following FORTRAN cards in EQCAL immediately following statement number 4 and its transfer card, if any, and immediately preceding statement number 6:

Column No. 5	7
5	CALL COOLR8
	RETURN

The insertion of the same subroutine as equipment subroutine number 15 would require the insertion of the following cards in the mainline program

immediately following statement number 14 and its following transfer card:

Column No.	4	7
	15	CALL COOLR8
		GO TO 7777

Or the addition of COOLR8 as equipment subroutine number 21 or any number greater than 21 would require the insertion of the following cards in the proper location following statement number 5201:

Column No.	4	7
	21	CALL COOLR8
		GO TO 7777

The removal of an equipment subroutine requires the reverse procedure--removal of the calling statement and the transfer card and replacement of these cards with the transfer card assigned the statement number of the deleted subroutine. For example, if equipment subroutine 15 were deleted the FORTRAN cards described above would be replaced by the following FORTRAN statement:

Column No.	4	7
	15	GO TO 7777

One additional change is required in addition to those decribed above when an equipment subroutine is incorporated into or removed from PACER. This change is necessary due to a feature of PACER which establishes the correlation between equipment subroutine names and numbers and permits the multiple calling of equipment subroutines for different equipments. That is equipments number 5 and 10 may both be pumps which can be calculated by subroutine PUMP5. This feature referred to as the LPHA listing stores the last three characters of the equipment subroutine name in the position corresponding to its equipment subroutine number. The format of the LPHA listing, I2/ (15A3, 10A3), permits the inclusion of the first 25 equipments on card 1. If 30 equipments were used two cards would be required--25 on the first card and 5 in the first 15 spaces of the second card. If an equipment subroutine number is not occupied, its three characters are left blank. A control card indicating the number of equipments for which an LPHA designation should be read precedes the LPHA listing and is indicated in the format statement as an I2 format.

If equipment subroutine COOLR8 were assigned subroutine number 15, the following entry would be made in column 43-45 of the first card of the LPHA listing:

Column No.	43 - 45
	L R 8

If equipment subroutine PUMP5 were designated equipment number 28 the following entry would be made in columns 10-12 of the second card of the LPHA listing:

Column No.	10 - 12
	P 5

If, on the other hand, equipment subroutine PUMP5 were removed from the PACER structure, columns 10-12 of the second card would be left blank.

Data Deck. The data deck is the means by which the user conveys to the PACER executive routine is a detailed discription of the system to be simulated. Only one simulation run may be processed for each data deck supplied. However, several simulation runs may be processed consecutively by providing consecutive data decks for each run.

In general, a data deck for a simulation run is composed of 15 groups of data. However, the first group, the LPHA listing, is provided only with the first data deck of a multi-deck execution. All decks after the first deck consist of only 14 data groups. The data groups and their required order of assembly are listed and discussed below. In addition, data decks for the six simulations run to test the feasibility of the modified PACER program are provided as illustrative examples at the end of this appendix. (See Figures A3. - A8.).

LPHA Listing. Format: I2/(15A3,10A3). This data group indicates the allowable names of PACER equipment subroutines and provides the requisite correspondence between the equipment subroutine number, the equipment subroutine name and the equipment number. The first card contains in I2 format the number of equipment names to be read from the LPHA listing. The remaining cards contain the LPHA listing of the last three characters of the allowable equipment subroutines. No redundancy is permitted in the three-character names although individual character redundancy is permitted. The absolute location of an equipment subroutine in the LPHA listing must coincide with the number assigned to the equipment

subroutine. That is, the equipment subroutine name placed in the 25th location in the LPHA listing must be the last three characters of equipment number 25.

Title Card. Format: 2(12A3). A single card provided for the assignment of a unique identifying title to each run.

Control Parameters. Format: 10I5. A list of 8 parameters which control the processing of PACER simulations. The parameters, in their order of listing on the input record, are:

1. KRUN - Run number.
2. KSETS - Controls intermediate printing of PACER status. Following is a listing of allowable values and options each provides.

Value	Option
0	Prints initial conditions of matrices, intermediate conditions of matrices every KPRINT loops and final results of run.
2	In addition to above, prints values in STRMI and STRMO after each calculation and number of stream variable deviations from convergence criteria.
3	In addition to above, prints flag lists for streams and equipments.

3. KCLEAN - If set equal to zero, it causes PACER to zero all matrices and vectors before reading in data.
4. LOOPS - Maximum number of loops to be permitted in iterative calculations.
5. NOGO - Controls simulation options if convergence is not obtained in number of LOOPS permitted. If NOGO = 0, the answers obtained during the last loop will be taken as correct and the calculation will continue. If NOGO $\neq$ 0, additional trial and error testing of assumed input streams will be made until either convergence is obtained, execution time expires or calculation is determined to be impossible.
6. KARDS - If greater than zero, provides a deck of cards punched with the stream variables matrix.
7. KPRINT - Controls number of loops between printout of stream variables matrix.
8. KONV - Not used. Leave blank.

Dimension Parameters. Format: 10I5. This data group contains nine parameters which control the allowable dimensions of a run. Any change in these variables requires an identical change to the parameter where it appears in the dimension deck. The following is a listing of the nine parameters in the order of their recording on the input record:

1. N2MAX - maximum number of rows permitted in the process matrix.

2. N3MAX - maximum number of columns permitted in process matrix.
3. NEMAX - maximum number of equipments permitted in system to be simulated.
4. NSMAX - maximum number of streams permitted in system to be simulated.
5. NELMAX - maximum number of columns permitted in EN matrix.
6. NECLMX - maximum number of columns permitted in equipment control matrix.
7. NSLMAX - maximum number of columns permitted in SN matrix.
8. NSCLMX - maximum number of columns permitted in stream variables control matrix.
9. NOCOMP - maximum number of components in each stream. Not used other than for information purposes.

Process Matrix (KPM). Format: I5, 1X2A3, 1X2A3, 1X9I5. The process matrix contains the topology or configuration of the system to be simulated. It is preceded by a single card (Format I5) which indicates the number of rows to be read in the process matrix. Each row corresponds to an equipment in the system configuration. Equipment numbers need not be consecutive but must be in ascending numerical order. The first item to be read from the input record (Format I5) is the equipment number. The second and third items are the first three and second three characters, respectively, of the 6 character equipment subroutine used to calculate that equipment. The next 9 items are the input and output streams for that equipment. Input streams are listed first and output streams, preceded by a negative sign, follow. A word of caution is necessary at this point. One must remember that equipment subroutines are written in anticipation of or in conjunction with the order of input and output streams. Accordingly, any changes in the order of input and output streams for an equipment must be checked against the equipment subroutine to insure that revised input/output stream listing is consistent with equipment subroutine. If a disparity exists either the equipment subroutine or the order of input/output streams must be revised to bring them into conformity with each other.

Equipment Parameter Matrix (EN). Format: 5F15.5. The EN matrix is preceded by a single control card (Format I5) which indicates the number of equipment parameters vectors to be read in the EN matrix. The first item read in an equipment parameters vector is the equipment number. The second item on the input record is not used and is left blank. The remaining thirteen items are the equipment parameters for the equipment in question.

The equipment parameters are unique for each equipment and normally represent such parameters as power, heat transfer coefficient, etc. The equipment parameters for each equipment employed in the steam power system are listed in Figure A9.

Equipment Control Parameters Matrix (ENC). Format: 5F15.5. The ENC matrix is preceded by a single card (Format I5) which indicates the number of rows in the ENC matrix. Representative data to be used in the ENC matrix would normally include allowable differentials across equipments, costs, etc. Control vectors are only included for those equipments which employ them. If no control vectors are employed, the control card should be punched zero or left blank and input/output should proceed to next data segment.

Stream Variables Matrix (SN). Format: 5FI5.5. The SN matrix is preceded by a single card which indicates number of stream vectors to be read into program. If control variable is zero or blank, the input/output will proceed to next data group. The stream variable matrix contains such variables as pressure, temperature, enthalpy, total steam flow, etc. This location labeling is consistent for each subroutine. The SN vector for the steam power system is structured as follows.

STRM.	FLAG	PRESSURE (PSIA)	TEMPERATURE (^{o}F)	ENTHALPY (BTU/LB)

SPEC. WT. (LB/FT^3)	VELOC. (FPS)	TOTAL FLOW (LB/HR)	H_2O FLOW (LB/HR)	STEAM FLOW (LB/HR)

INPURITIES FLOW (LB/HR)	AIR FLOW (LB/HR)	FUEL FLOW (LB/HR)	FLUE GAS FLOW (LB/HR)	COOLANT FLOW (LB/HR)

Stream Control Matrix (SNC). Format: 5FI5.5. A single card precedes SNC and indicates number of stream control variable vectors to be read. If this value is zero, PACER proceeds to next data group in data deck. The SNC matrix contains control parameters such as viscosity, volume, etc. The distinction between the variables specified for this matrix and that provided for SN are arbitrary and lack discrimination. Accordingly, SNC need not be used unless required. It is not employed in the steam power cycle.

Stream Variables Test Vector (DELS). Format: 5FI5.5. This group is preceded by a single card (Format I5) which indicates test vectors is to be read from DELS matrix. If control card = 0, no test vector is to be read and PACER skips to next data group. If control card value $\neq 0$ then PACER will read one test vector NSLMAX long. This same test vector will be used as test vector for determining convergence of each stream variable for all streams.

Stream Control Variables Test Vector (DELSC). Format: 5FI5.5. Preceded by single control card which indicates if test vector is employed. If control card value = 0 (Format I5) then no control test vector is employed and PACER will proceed to next data group. If control card value $\neq 0$, then test vector is employed and is NSCLMX long. Only one test vector is employed for stream control variables for all streams employing control variables. This test vector will check convergence of control variables for all streams employing control variables.

Preferred Stream Numbers (KPS). Format: 10I5. KPS is preceded by a control card (Format I5) which indicates number of preferred streams. If control card value equals zero, then PACER proceeds to next data group. If control card $\neq 0$, PACER reads numbers of preferred streams, i. e. those streams which will be assumed known first in a trial and error calculation to determine order of calculations. Normally these should be recycle or other internal streams since feed and product streams are assumed known in trial and error calculations.

Extra Equipment Vectors (AEN). Format: 5FI5.5. AEN is preceded by a control card. If control card value (Format I5) equals zero, PACER will proceed to next data group. If control value $\neq 0$, PACER reads into AEN extra equipment parameters for number of equipments indicated on

control card. This matrix is only used if insufficient space is available in EN and ENC. Length of vector is arbitrarily established at 40.

<u>Order of Equipment Calculation (NELIST)</u>. Format: 10I5. NELIST is preceded by a control card which indicates number of equipments contained in NELIST matrix. If the order of calculation is not specified, the control card value (Format 10I5) equals zero and PACER proceeds to next data group. Each card consists of five pairs of data. The first value of a pair represents the equipment number. The second value represents the calculational mode for that equipment. If mode indicator equals one, the equipment will be calculated directly. If the mode indicator equals two, the equipment will be calculated as an equipment in an iterative list of equipment. Finally, if mode indicator equals three, the equipment will be calculated as last item in list of equipment to be calculated in an iterative mode.

<u>Selected Streams Vector (KSPRNT)</u>. Format: 16I5. Contains as the first item the number of stream variable vectors to be printed each iteration. If it is not desired to print any stream variable vectors each iteration the card should be left blank. The stream numbers for which the stream variables are to be printed are listed after the first item. A maximum of 15 stream variable vectors may be printed each iteration.

```
C*****LPHA LISTING
30
BN5NR5P5 P6 MR5NR6LR5TR5HR5TR6LR6R5

C*****TITLE CARD
SIMULATION OF NON-REGENERATIVE STEAM POWER PLANT USING REVISED PACER  01
C*****CONTROL PARAMETERS
    1          50    1        1
C*****DIMENSION PARAMETERS
   30    9   30   36   15    5   15    5    8
C*****PROCESS MATRIX (KPM)
   13
    1 TURBN5          1   -2
    2 CNDNR5          2    3    6   36   -4   -5   -7
    3 PUMP5           8    9   -6  -10
    4 PUMP6           5   12  -11  -13
    5 HTRMR5         11   13   10   17   32   28  -14
    6 PUMP6          14   16  -15  -17
    7 ECONR6         15   35  -18  -33
    8 BOILR5         18   20  -23  -22  -19
    9 SPLTR5         19  -31  -34   -9  -12  -27  -16
   10 SPRHR5         34   24  -25   -1
   11 FOHTR6         21   26   27  -24  -20  -28
   12 FDBLR6         29   31  -30  -32
   13 MIXR5          25   22   30  -35
C*****EQUIPMENT PARAMETERS MATRIX (EN)
   13
1.                                   20000.        928.         80.
          90.

2.                                       .00005          .003          .97
         650.

3.                                           70.      93.        996.

4.                                   70.           93.           996.

5.                                     1.

6.                                    70.          93.           996.

7.                                  300.          1.             .2

8.                                  .88           .12
               200.                 80.            449.4

9.

10.                                    .88         .12
                                        80.

11.                                  .48

12.                               60.             95.            4.
  45.              32.               26.            115.            109.
  996.
  13.

  C*****EQUIPMENT PARAMETERS CONTROL MATRIX (ENC)
```

Figure A3. Data Deck for Run 01 - Basic System, Order of Calculations Specified

```
C*****STREAM VARIABLES MATRIX (SN)
   36
1.                      500.        680.        1344.

2.                      2.            126.

3.                       15.        80.           49.

4.                         15.      126.           94.

5.                       2.           126.         94.
62.4

6.                      30.           70.

7.                       30.           95.

8.                      15.           70.
64.

9.                      500.          467.          1205.

10.                     30.          250.

11.                      30.
62.4

12.                      500.         467.          1205.

13.                     30.              250.

14.                      30.
62.4

15.                        500.
62.4

16.                     500.          467.         1205.

17.                      30.           250.

18.                       500.         367.          339.

19.                       500.         467.         1205.

20.                      30.           140.

21.                     15.            70.

22.                      30.          140.

23.                       500.           467.           449.
```

Figure A3. Contd

```
24.                             30.          140.

25.                              30.        140.

26.                            15.           70.

27.                             30.          335.         1205.

28.                             30.          250.            219.

29.                          15.             80.

30.                            15.            80.
                    300.
31.                           500.          467.            1205.

32.                            30.             250.

33.                             15.

34.                           500.          467.           1205.

35.                           15.            3000.

36.                               15.            70.       38.

C*****STREAM VARIABLES CONTROL MATRIX (SNC)

C*****STREAM VARIABLES CONVERGENCE CONTROL CRITERIA (DELS)
    1
1.                 1.              1.              .02            .02


1.                 1.            .02               .02            .02
.02               .02             .02              .02           .02
C*****STREAM CONTROL VARIABLES CONVERGENCE CRITERIA (DELSC)

C*****PREFERRED STREAMS LISTING (KPS)
    4
   36   32   17   28
C*****EXTRA EQUIPMENT MATRIX (AEN)

C*****ORDER OF CALCULATIONS LISTING (NELIST)
   13
    1    1    2    2    3    2    4    2    5    2
    6    2    8    2_   9    2   10    2   11    2
   12    2   13    2    7    3
C*****SELECTED STREAMS PRINTOUT LIST (KSPRNT)
```

Figure A3 Contd.

```
C*****LPHA LISTING
30
BN5NR5P5 P6 MR5NR6LR5TR5HR5TR6LR6R5

C*****TITLE CARD
SIMULATION OF NON-REGENERATIVE STEAM POWER PLANT USING REVISED PACER  02
C*****CONTROL PARAMETERS
    2            50    1         1
C*****DIMENSION PARAMETERS
   30    9   30   36   15    5   15    5    8
C*****PROCESS MATRIX (KPM)
   12
    1 TURBN5             1   -2
    2 CNDNR5             2    3    6   36   -4   -5   -7
    3 PUMP5              8    9   -6  -10
    4 PUMP6              5   12  -11  -13
    5 HTRMR5            11   13   10   17   32   28  -14
    6 PUMP6             14   16  -15  -17
    7 ECONR6            15   35  -18  -33
    8 BOILR5            18   20  -23  -22  -19
    9 SPLTR5            19  -31   -1   -9  -12  -27  -16
   11 FOHTR6            21   26   27  -24  -20  -28
   12 FDBLR6            29   31  -30  -32
   13 MIXR5             25   22   30  -35
C*****EQUIPMENT PARAMETERS MATRIX (EN)
   12
1.                              20000.          850.          80.
         90.

2.                                   .00005          .003            .97
        650.

3.                                     70.      93.           996.

4.                               70.           93.            996.

5.                                   1.

6.                                70.           93.            996.

7.                              300.         1.                .2

8.                              .88          .12
              200.              80.            449.4

9.

11.                              .48

12.                            60.             95.            4.
45.            32.               26.           115.           109.
996.
13.

 C*****EQUIPMENT PARAMETERS CONTROL MATRIX (ENC)
```

Figure A4. Data Deck for Run 02 - Basic System Without Superheater, Order of Calculations Specified

```
C*****STREAM VARIABLES MATRIX (SN)
   35
 1.                    500.      467.      1205.

 2.                    2.        126.

 3.                    15.       80.       49.

 4.                    15.       126.      94.

 5.                    2.        126.      94.
62.4
 6.                    30.       70.

 7.                    30.       95.

 8.                    15.       70.
64.
 9.                    500.      467.      1205.

10.                    30.       250.

11.                    30.
62.4
12.                    500.      467.      1205.

13.                    30.       250.

14.                    30.
62.4
15.                    500.
62.4
16.                    500.      467.      1205.

17.                    30.       250.

18.                    500.      367.      339.

19.                    500.      467.      1205.

20.                    30.       140.

21.                    15.       70.

22.                    30.       140.
```

Figure A4. Contd

```
23.                              500.           467.            449.

24.                              30.            140.

25.                               30.         140.

26.                            15.            70.

27.                              30.            335.         1205.

28.                              30.            250.            219.

29.                         15.               80.

30.                            15.              80.
                   300.
31.                            500.          467.            1205.

32.                            30.               250.

33.                              15.

35.                         15.               3000.

36.                                 15.            70.        38.

C*****STREAM VARIABLES CONTROL MATRIX (SNC)

C*****STREAM VARIABLES CONVERGENCE CONTROL CRITERIA (DELS)
    1
1.                 1.              1.              .02              .02
1.                  1.            .02              .02              .02
.02                 .02            .02              .02             .02
C*****STREAM CONTROL VARIABLES CONVERGENCE CRITERIA (DELSC)

C*****PREFERRED STREAMS LISTING (KPS)
    4
   36   32   17   28


C*****EXTRA EQUIPMENT MATRIX (AEN)

C*****ORDER OF CALCULATIONS LISTING (NELIST)
   12
    1     1     2     2     3     2     4     2     5     2
    6     2     7     2     8     2     9     2    11     2
   12     2    13     3
C*****SELECTED STREAMS PRINTOUT LIST (KSPRNT)
```

Figure A4. Contd

```
C*****LPHA LISTING
30
BN5NR5P5 P6 MR5NR6LR5TR5HR5TR6LR6R5

C*****TITLE CARD
SIMULATION OF NON-REGENERATIVE STEAM POWER PLANT USING REVISED PACER  02
C*****CONTROL PARAMETERS
    2           50    1          1
C*****DIMENSION PARAMETERS
   30    9   30   36   15    5   15    5    8
C*****PROCESS MATRIX (KPM)
   12
    1 TURBN5             1   -2
    2 CNDNR5             2    3    6   36   -4   -5   -7
    3 PUMP5              8    9   -6  -10
    4 PUMP6              5   12  -11  -13
    5 HTRMR5            11   13   10   17   32   28  -14
    6 PUMP6             14   16  -15  -17
    7 ECONR6            15   35  -18  -33
    8 BOILR5            18   20  -23  -22  -19
    9 SPLTR5            17  -31   -1   -9  -12  -27  -16
   11 FOHTR6            21   26   27  -24  -20  -28
   12 FDBLR6            29   31  -30  -32
   13 MIXR5             25   22   30  -35
C*****EQUIPMENT PARAMETERS MATRIX (EN)
   12
1.                            20000.         850.          80.
          90.
2.                                 .00005          .003           .97
         650.
3.                                    70.     93.          996.

4.                             70.           93.           996.

5.                                 1.

6.                              70.           93.           996.

7.                            300.        1.                .2

8.                            .88         .12
                 200.         80.            449.4
9.

11.                            .48

12.                         60.            95.            4.
45.              32.          26.           115.          109.
996.
13.
```

Figure A5. Data Deck for Run 02 Basic System Without Superheater, Order of Calculations Not Specified

```
C*****EQUIPMENT PARAMETERS CONTROL MATRIX (ENC)

C*****STREAM VARIABLES MATRIX (SN)
   35
1.                                       500.          467.          1205.

2.                                       2.              126.

3.                                        15.          80.             49.

4.                                           15.       126.             94.

5.                                        2.             126.          94.
62.4
6.                                       30.             70.

7.                                        30.             95.

8.                                       15.             70.
64.
9.                                       500.            467.          1205.

10.                                      30.            250.

11.                                       30.
62.4
12.                                       500.           467.          1205.

13.                                      30.                250.

14.                                       30.
62.4
15.                                          500.
62.4
16.                                      500.            467.          1205.

17.                                      .30.             250.

18.                                         500.         367.           339.

19.                                         500.         467.          1205.
```

Figure A5. Contd.

```
20.                                30.          140.
21.                               15.           70.
22.                                30.          140.
23.                                 500.          467.             449.
24.                                 30.         140.
25.                                  30.        140.
26.                                15.          70.
27.                                 30.         335.         1205.
28.                                 30.         250.               219.
29.                             15.             80.
30.                                15.            80.
                    300.
31.                               500.        467.               1205.
32.                                30.             250.
33.                                 15.
35.                              15.            3000.
36.                                   15.            70.      38.
C*****STREAM VARIABLES CONTROL MATRIX (SNC)
C*****STREAM VARIABLES CONVERGENCE CONTROL CRITERIA (DELS)
    1
1.                 1.             1.             .02            .02
1.                  1.           .02             .02            .02
.02                 .02           .02             .02           .02
C*****STREAM CONTROL VARIABLES CONVERGENCE CRITERIA (DELSC)
C*****PREFERRED STREAMS LISTING (KPS)
    4
   36   32   17   28
C*****EXTRA EQUIPMENT MATRIX (AEN)
C*****ORDER OF CALCULATIONS LISTING (NELIST)
C*****SELECTED STREAMS PRINTOUT LIST (KSPRNT)
```

Figure A5. Contd

```
C*****LPHA LISTING
30
BN5NR5P5 P6 MR5NR6LR5TR5HR5TR6LR6R5

C*****TITLE CARD
SIMULATION OF NON-REGENERATIVE STEAM POWER PLANT USING REVISED PACER 03
C*****CONTROL PARAMETERS
   3            50    1          1
C*****DIMENSION PARAMETERS
  30    9   30   36   15    5   15    5    8
C*****PROCESS MATRIX (KPM)
  13
   1 TURBN5              1   -2
   2 CNDNR5              2    3    6   36   -4   -5   -7
   3 PUMP5               8    9   -6  -10
   4 PUMP6               5   12  -11  -13.
   5 HTRMR5             11   13   10   17   32   28  -14
   6 PUMP6              14   16  -15  -17
   7 ECONR6             15   35  -18  -33
   8 BOILR5             18   20  -23  -22  -19
   9 SPLTR5             19  -31  -34   -9  -12  -27  -16
  10 SPRHR5             34   24  -25   -1
  11 FOHTR6             21   26   27  -24  -20  -28
  12 FDBLR6             29   31  -30  -32
  13 MIXR5              25   22   30  -35
C*****EQUIPMENT PARAMETERS MATRIX (EN)
  13
1.                              20000.         928.          80.
          90.

2.                                  .00005           .003              .97
         650.

3.                                       70.       93.          996.

4.                             70.             93.          996.

5.                                 1.

6.                              70.            93.          996.

7.                            300.          1.               .2

8.                            .88           .12
                 200.         80.            449.4

9.

10.                               .88          .12
                                   80.

11.                            .48

12.                          60.             95.          4.
```

Figure A6. Data Deck for Run 03 - Basic System, Order of Calculations Not Specified

```
45.            32.          26.          115.          109.
996.
13.

C*****EQUIPMENT PARAMETERS CONTROL MATRIX (ENC)

C*****STREAM VARIABLES MATRIX (SN)
  36
1.                          500.         680.          1344.

2.                          2.             126.

3.                           15.         80.            49.

4.                             15.       126.           94.

5.                           2.            126.         94.
62.4

6.                          30.            70.

7.                           30.           95.

8.                          15.            70.
64.

9.                          500.           467.          1205.

10.                         30.          250.

11.                          30.
62.4

12.                          500.          467.          1205.

13.                         30.              250.

14.                          30.
62.4

15.                            500.
62.4

16.                         500.           457.         1205.

17.                          30.            250.

18.                           500.         357.          339.
```

Figure A6. Contd

```
19.                          500.          467.          1205.

20.                         30.           140.

21.                        15.            70.

22.                         30.          140.

23.                          500.           467.            449.

24.                          30.            140.

25.                           30.        140.

26.                         15.           70.

27.                          30.          335.          1205.

28.                          30.          250.             219.

29.                      15.              80.

30.                         15.             80.
                300.
31.                        500.          467.             1205.

32.                         30.             250.

33.                          15.

34.                        500.          467.            1205.

35.                       15.             3000.

36.                            15.            70.        33.

C*****STREAM VARIABLES CONTROL MATRIX (SNC)

C*****STREAM VARIABLES CONVERGENCE CONTROL CRITERIA (DELS)
    1   .
1.              1.         1.           .02           .02
```

Figure A6. Contd

```
1.                  1.           .02                .02              .02
.02                 .02           .02               .02             .02
C*****STREAM CONTROL VARIABLES CONVERGENCE CRITERIA (DELSC)

C*****PREFERRED STREAMS LISTING (KPS)
    4
  36   32   17   28
C*****EXTRA EQUIPMENT MATRIX (AEN)

C*****ORDER OF CALCULATIONS LISTING (NELIST)

C*****SELECTED STREAMS PRINTOUT LIST (KSPRNT)
```

Figure A6. Contd

```
C*****LPHA LISTING
30
BN5NR5P5 P6 MR5NR6LR5TR5HR5TR6LR6R5

C*****TITLE CARD
SIMULATION OF A STEAM POWER SYSTEM WITHOUT AN ECONOMIZER 04
C*****CONTROL PARAMETERS
    4              50   1         1
C*****DIMENSION PARAMETERS
   30    9   30   36   15    5   15    5    8
C*****PROCESS MATRIX (KPM)
   12
    1 TURBN5              1   -2
    2 CNDNR5              2    3    6   36   -4   -5   -7
    3 PUMP5               8    9   -6  -10
    4 PUMP6               5   12  -11  -13
    5 HTRMR5             11  -13   10   17   32   28  -14
    6 PUMP6              14   16  -15  -17
    8 BOILR5             15   20  -23  -22  -19
    9 SPLTR5             19  -31  -34   -9  -12  -27  -16
   10 SPRHR5             34   24  -25   -1
   11 FOHTR6             21   26   27  -24  -20  -28
   12 FDBLR6             29   31  -30  -32
   13 MIXR5              25   22   30  -35
C*****EQUIPMENT PARAMETERS MATRIX (EN)
   12
1.                                  20000.        928.          80.
           90.

2.                                      .00005           .003           .97
          650.

3.                                         70.       93.          996.

4.                                 70.            93.          996.

5.                                      1.

6.                                 70.           93.           996.

8.                               .88          .12
                 200.            80.            449.4

9.

10.                                     .88          .12
                                        80.

11.                                .48

12.                            60.            95.           4.
45.             32.            26.            115.          109.
996.
13.


C*****EQUIPMENT PARAMETERS CONTROL MATRIX (ENC)

C*****STREAM VARIABLES MATRIX (SN)
   34
1.                             500.           680.          1344.

2.                             2.                126.

3.                               15.          80.             49.

4.                                  15.       126.            94.
```

Figure A7. Data Deck for Run 04 - Basic System Without Economizer, Order of Calculations Specified

5. 62.4		2.	126.	94.
6.		30.	70.	
7.		30.	95.	
8. 64.		15.	70.	
9.		500.	467.	1205.
10.		30.	250.	
11. 62.4		30.		
12.		500.	467.	1205.
13.		30.	250.	
14. 62.4		30.		
15. 62.4		500.		
16.		500.	467.	1205.
17.		30.	250.	
19.		500.	467.	1205.
20.		30.	140.	
21.		15.	70.	
22.		30.	140.	
23.		500.	467.	449.
24.		30.	140.	
25.		30.	140.	
26.		15.	70.	
27.		30.	335.	1205.
28.		30.	250.	219.
29.		15.	80.	
30.	300.	15.	80.	

Figure A7. Contd.

```
31.                     500.          467.           1205.

32.                      30.            250.

34.                     500.          467.          1205.

35.                    15.              3000.

36.                          15.            70.       38.

C*****STREAM VARIABLES CONTROL MATRIX (SNC)

C*****STREAM VARIABLES CONVERGENCE CONTROL CRITERIA (DELS)
    1
1.              1.           1.            .02           .02
1.               1.         .02            .02           .02
.02              .02         .02           .02          .02
C*****STREAM CONTROL VARIABLES CONVERGENCE CRITERIA (DELSC)

C*****PREFERRED STREAMS LISTING (KPS)
    4
   36   32   17   28
C*****EXTRA EQUIPMENT MATRIX (AEN)

C*****ORDER OF CALCULATIONS LISTING (NELIST)

    12
     1    1    2    2    3    2    4    2    5    2
     6    2    8    2    9    2   10    2   11    2
    12    2   13    3
C*****SELECTED STREAMS PRINTOUT LIST (KSPRNT)
```

Figure A7. Contd.

```
C*****LPHA LISTING
30
BN5NR5P5 P6 MR5NR6LR5TR5HR5TR6LR6R5

C*****TITLE CARD
SIMULATION OF A STEAM POWER SYSTEM WITHOUT AN ECONOMIZER 04
C*****CONTROL PARAMETERS
    4          50    1          1
C*****DIMENSION PARAMETERS
   30    9   30   36   15    5   15    5    8
C*****PROCESS MATRIX (KPM)
   12
    1 TURBN5             1   -2
    2 CNDNR5             2    3    6   36   -4   -5   -7
    3 PUMP5              8    9   -6  -10
    4 PUMP6              5   12  -11  -13
    5 HTRMR5            11   13   10   17   32   28  -14
    6 PUMP6             14   16  -15  -17
    8 BOILR5            15   20  -23  -22  -19
    9 SPLTR5            19  -31  -34   -9  -12  -27  -16
   10 SPRHR5            34   24  -25   -1
   11 FOHTR6            21   26   27  -24  -20  -28
   12 FDBLR6            29   31  -30  -32
   13 MIXR5             25   22   30  -35
C*****EQUIPMENT PARAMETERS MATRIX (EN)
   12
1.                              20000.        928.         80.
          90.

2.                                  .00005          .003           .97
         650.

3.                                    70.       93.          996.

4.                             70.            93.          996.

5.                                 1.

6.                              70.           93.            996.

8.                          .88           .12
                 200.       80.           449.4

9.

10.                             .88           .12
                                80.

11.                          .48

12.                       60.            95.          4.
45.              32.        26.           115.         109.
996.
13.
```

Figure A3 Data Deck for Run 04 - Basic System Without Economizer, Order of Calculations Not Specified

```
C*****EQUIPMENT PARAMETERS CONTROL MATRIX (ENC)

C*****STREAM VARIABLES MATRIX (SN)
   34
 1.                    500.        680.        1344.

 2.                      2.          126.

 3.                     15.        80.          49.

 4.                        15.     126.          94.

 5.                      2.          126.        94.
62.4
 6.                    30.           70.

 7.                     30.           95.

 8.                    15.           70.
64.
 9.                    500.        467.         1205.

10.                    30.         250.

11.                     30.
62.4
12.                     500.       467.         1205.

13.                    30.             250.

14.                     30.
62.4
15.                        500.
62.4
16.                   500.         467.        1205.

17.                     30.          250.

19.                      500.      467.        1205.

20.                     30.        140.
```

Figure A8. Contd

```
21.                          15.         70.

22.                           30.       140.

23.                            500.       467.        449.

24.                            30.        140.

25.                             30.     140.

26.                           15.         70.

27.                            30.        335.      1205.

28.                            30.        250.         219.

29.                        15.            80.

30.                           15.          80.
                300.
31.                          500.       467.         1205.

32.                           30.          250.

34.                          500.       467.        1205.

35.                         15.          3000.

36.                               15.         70.       38.

C*****STREAM VARIABLES CONTROL MATRIX (SNC)

C*****STREAM VARIABLES CONVERGENCE CONTROL CRITERIA (DELS)
    1
1.              1.           1.            .02          .02
1.               1.         .02            .02          .02
.02              .02         .02           .02         .02
C*****STREAM CONTROL VARIABLES CONVERGENCE CRITERIA (DELSC)

C*****PREFERRED STREAMS LISTING (KPS)
    4
   36   32   17   28
C*****EXTRA EQUIPMENT MATRIX (AEN)

C*****ORDER OF CALCULATIONS LISTING (NELIST)

C*****SELECTED STREAMS PRINTOUT LIST (KSPRNT)
```

Figure A8. Contd.

EQPT. NO.	EQPT. FLAG	EQUIPMENT PARAMETERS												
1		POWER (HP)	ISENTROPIC ENTHALPY (BTU/LB)	ENGINE EFFICIENCY (%)	MECH. EFFICIENCY (%)									
2		INPUR. FACTOR (LB/LB STM.)	LOSS FACTOR (LB/LB STM.)	SPECIFIC HEAT COOLANT (BTU/LB °F)	HEAT TRANSFER COEFFICIENT (BTU/HR °F FT²)									
3		ENGINE EFFIC. (%)	MECH. EFFIC. (%)	ISENTROPIC ENTHALPY (BTU/LB)										
4		ENGINE EFFIC. (%)	MECH. EFFIC. (%)	ISENTROPIC ENTHALPY (BTU/LB)										
5														
6		ENGINE EFFIC. (%)	MECH. EFFIC. (%)	ISENTROPIC ENTHALPY (BTU/LB)										
7		HEAT TRANSF. COEFF. (BTU/HR °F FT²)	SPECIFIC HEAT COOLER FLUID (BTU/LB °F)	SPECIFIC HEAT HOTER FLUID (BTU/LB °F)										
8		WEIGHT FRACTION C IN FUEL	WEIGHT FRACTION H IN FUEL			BLOWDOWN FACTOR (LB H_2O/LB IN FUR.)	BOILER EFFIC. (%)	SAT. LIQ. (BTU/LB)						
9														
10		WEIGHT FRACTION C IN FUEL	WEIGHT FRACTION H IN FUEL				BOILER EFFIC. (%)							
11		SPECIFIC HEAT FUEL OIL (BTU/LB °F)												
12		ENGINE EFFICIENCY (%)	MECH EFFICIENCY (%)	FUEL STOICHIOMETRIC COEFFICIENT	AIR STOICHIOMETRIC COEFFICIENT	CO_2 STOICHIOMETRIC COEFFICIENT	EXCESS AIR (%)	MOLECULAR WT. FUEL (LB/MOLE)	ISENTROPIC ENTHALPY (BTU/LB)					
13														

Figure A9. Steam Power System Equipment Parameters Matrix Legend

Appendix B

RESULTS OF TESTS

Format and Interpretation of Results. As discussed in Chapter V, six simulation tests were developed to test the validity of the revisions made to the original PACER program, the efficacy of PACER as a simulation device and the potential usefulness of PACER as an instructional device in a chemical engineering curriculum. The results of those simulation tests are presented as Figures B1. - B6.

The final values of the stream variables matrix and the equipment parameters matrix are presented for each run. In addition for runs 01 and 03 extensive diagnostics of the PACER solution process are presented for analysis by the user. This is a PACER option. The stream variables are consistent for all streams in the stream variables matrix. That is, stream variable 5 will represent enthalpy for all streams. However, the enthalpy for all streams will not necessarily be the same.

For the steam power system developed for this project, the following stream variable arrangement was decided on and should be used as a guide in interpreting values of stream variables in the stream variables matrix. Note that there are five columns in each stream. This dimension may be parametically varied by the user by adjusting dimensions of SN matrix.

STRM.	FLAG	PRESSURE (PSIA)	TEMPERATURE (^{o}F)	ENTHALPY (BTU/LB)

SPEC. WT. (LB/FT^3)	VELOC. (FPS)	TOTAL FLOW (LB/HR)	H_2O FLOW (LB/HR)	STEAM FLOW (LB/HR)

INPURITIES FLOW (LB/HR)	AIR FLOW (LB/HR)	FUEL FLOW (LB/HR)	FLUE GAS FLOW (LB/HR)	COOLANT FLOW (LB/HR)

```
                CALCULATION ORDER
                 EQUIPMENT  CODE
                     1        1
                     2        2
                     3        2
                     4        2
                     5        2
                     6        2
                     8        2
                     9        2
                    10        2
                    11        2
                    12        2
                    13        2
                     7        3

     13 EQUIPMENT INTERCONNECTED BY     36 STREAMS.

    EQUIPMENT NUMBER     1  IS BEING CALCULATED DIRECTLY.

   ITERATIVE CALCULATION-ASSUMED INPUT STREAMS ARE

      0          0          0
     12  EQUIPMENT CALCULATED IN THE ORDER

             2    3    4    5    6    8    9   10   11   12
            13    7

 CONDENSER SURFACE AREA REQUIRED =    5654.21SQ. FT.
<*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*>
  TRACE OF CALLS IN REVERSE ORDER   ERROR NO. 10
      CALLING        ID      ABSOLUTE     ARGUMENT         ARGUMENT       ARGUMENT       ARGUMENT       ARGUMENT
      ROUTINE        #       LOCATION        #1               #2             #3             #4             #5
      ALOG10        36       057430     000000000012
      ECONR6         9       060417     001344217536
      EQCAL         25       074210
      ......        90       074752
 LOG(-B) NOT ALLOWED
 EVALUATE FOR +B
<*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*>

 ECONOMIZER SURFACE AREA REQUIRED =     -9.66SQ. FT.
```

Figure B1. Computer Calculations for Run 01 - Basic System, Order of Calculations Specified

STREAM VARIABLES MATRIX AT RUN 1 LOOP 1

1,0000	0,	500,0000	680,0000	1344,0000
0,	0,	169938,5684	0,	169938,5684
0,	0,	0,	0,	0,
2,0000	0,	2,0000	126,0000	1011,2000
0,	0,	169938,5684	0,	169938,5684
0,	0,	0,	0,	0,
3,0000	1,0000	15,0000	80,0000	49,0000
0,	0,	8,4969	0,	0,
8,4969	0,	0,	0,	0,
4,0000	2,0000	15,0000	126,0000	94,0000
0,	0,	509,8157	0,	509,8157
0,	0,	0,	0,	0,
5,0000	0,	2,0000	126,0000	94,0000
62,4000	0,	169947,0645	169938,5664	0,
8,4969	0,	0,	0,	0,
6,0000	0,	30,0000	70,0000	0,
0,	0,	6407056,3750	0,	0,
0,	0,	0,	0,	6407056,3750
7,0000	2,0000	30,0000	95,0000	0,
0,	0,	6407056,3750	0,	0,
0,	0,	0,	0,	6407056,3750
8,0000	1,0000	15,0000	70,0000	0,
64,0000	0,	6407056,3750	0,	0,
0,	0,	0,	0,	6407056,3750
9,0000	0,	500,0000	467,0000	1205,0000
0,	0,	2042,9088	0,	2042,9088
0,	0,	0,	0,	0,
10,0000	0,	30,0000	250,0000	1058,7000
0,	0,	2042,9088	0,	2042,9088
0,	0,	0,	0,	0,
11,0000	0,	30,0000	126,0000	94,0831
62,4000	0,	169947,0645	169938,5664	0,
8,4969	0,	0,	0,	0,
12,0000	0,	500,0000	467,0000	1205,0000
0,	0,	103,7448	0,	103,7448
0,	0,	0,	0,	0,
13,0000	0,	30,0000	250,0000	1058,7000
0,	0,	103,7448	0,	103,7448
0,	0,	0,	0,	0,
14,0000	0,	30,0000	138,0324	106,1155

Figure B1. Contd.

62.4000	0.	172093.7168	172085.2187	0.
8.4969	0.	0.	0.	0.
15.0000	0.	500.0000	138.0324	107.5103
62.4000	0.	172093.7168	172085.2187	0.
8.4969	0.	0.	0.	0.
16.0000	0.	500.0000	467.0000	1205.0000
0.	0.	1763.4267	0.	1763.4267
0.	0.	0.	0.	0.
17.0000	0.	30.0000	250.0000	1058.7000
0.	0.	1763.4267	0.	1763.4267
0.	0.	0.	0.	0.
18.0000	0.	500.0000	367.0000	339.0000
0.	0.	172093.7168	172085.2187	0.
8.4969	0.	0.	0.	0.
19.0000	0.	500.0000	467.0000	1205.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
20.0000	0.	30.0000	140.0000	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
21.0000	1.0000	15.0000	70.0000	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
22.0000	0.	30.0000	140.0000	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
23.0000	2.0000	500.0000	467.0000	449.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
24.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
25.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
26.0000	1.0000	15.0000	70.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
27.0000	0.	30.0000	335.0000	1205.0000
0.	0.	49.5952	0.	49.5952
0.	0.	0.	0.	0.
28.0000	0.	30.0000	250.0000	219.0000
0.	0.	49.5952	0.	49.5952
0.	0.	0.	0.	0.

Figure B1. Contd.

29,0000	1,0000	15,0000	80,0000	0,
0,	0,	23810,9460	0,	0,
0,	23810,9460	0,	0,	0,
30,0000	0,	15,0000	80,0000	0,
0,	300,0000	23810,9460	0,	0,
0,	23810,9460	0,	0,	0,
31,0000	0,	500,0000	467,0000	1205,0000
0,	0,	359,0544	0,	359,0544
0,	0,	0,	0,	0,
32,0000	0,	30,0000	250,0000	1079,6000
0,	0,	359,0544	0,	359,0544
0,	0,	0,	0,	0,
33,0000	2,0000	15,0000	-4797,7070	0,
0,	0,	25266,3296	0,	0,
0,	0,	0,	-25266,3296	0,
34,0000	0,	500,0000	467,0000	1205,0000
0,	0,	169938,5684	0,	0,
0,	0,	0,	0,	0,
35,0000	0,	15,0000	3000,0000	0,
0,	0,	25266,3296	0,	0,
0,	0,	0,	25266,3296	0,
36,0000	1,0000	15,0000	70,0000	38,0000
0,	0,	509,8157	509,8157	0,
0,	0,	0,	0,	0,

CONDENSER SURFACE AREA REQUIRED = 5654,2150, FT,

ECONOMIZER SURFACE AREA REQUIRED = 58,2980, FT,

Figure B1. Contd

STREAM VARIABLES MATRIX AT RUN 1 LOOP 2

1.0000	0.	500.0000	680.0000	1344.0000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
2.0000	0.	2.0000	126.0000	1011.2000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
3.0000	1.0000	15.0000	80.0000	49.0000
0.	0.	8.4969	0.	0.
8.4969	0.	0.	0.	0.
4.0000	2.0000	15.0000	126.0000	94.0000
0.	0.	509.8157	0.	509.8157
0.	0.	0.	0.	0.
5.0000	0.	2.0000	126.0000	94.0000
62.4000	0.	169947.0645	169938.5664	0.
8.4969	0.	0.	0.	0.
6.0000	0.	30.0000	70.0000	0.
0.	0.	6407056.3750	0.	0.
0.	0.	0.	0.	6407056.3750
7.0000	2.0000	30.0000	95.0000	0.
0.	0.	6407056.3750	0.	0.
0.	0.	0.	0.	6407056.3750
8.0000	1.0000	15.0000	70.0000	0.
64.0000	0.	6407056.3750	0.	0.
0.	0.	0.	0.	6407056.3750
9.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2042.9088	0.	2042.9088
0.	0.	0.	0.	0.
10.0000	0.	30.0000	250.0000	1058.7000
0.	0.	2042.9088	0.	2042.9088
0.	0.	0.	0.	0.
11.0000	0.	30.0000	126.0000	94.0831
62.4000	0.	169947.0645	169938.5664	0.
8.4969	0.	0.	0.	0.
12.0000	0.	500.0000	467.0000	1205.0000
0.	0.	103.7448	0.	103.7448
0.	0.	0.	0.	0.
13.0000	0.	30.0000	250.0000	1058.7000
0.	0.	103.7448	0.	103.7448
0.	0.	0.	0.	0.
14.0000	0.	30.0000	149.7096	117.7927

Figure B1. Contd.

62.4000	0.	174265.7891	174257.2910	0.
8.4969	0.	0.	0.	0.
15.0000	0.	500.0000	149.7096	119.1876
62.4000	0.	174265.7891	174257.2910	0.
8.4969	0.	0.	0.	0.
16.0000	0.	500.0000	467.0000	1205.0000
0.	0.	1785.6837	0.	1785.6837
0.	0.	0.	0.	0.
17.0000	0.	30.0000	250.0000	1058.7000
0.	0.	1785.6837	0.	1785.6837
0.	0.	0.	0.	0.
18.0000	0.	500.0000	367.0000	339.0000
0.	0.	174265.7891	174257.2910	0.
8.4969	0.	0.	0.	0.
19.0000	0.	500.0000	467.0000	1205.0000
0.	0.	170385.8340	0.	170385.8340
0.	0.	0.	0.	0.
20.0000	0.	30.0000	140.0000	0.
0.	0.	9102.8365	0.	0.
0.	0.	9102.8365	0.	0.
21.0000	1.0000	15.0000	70.0000	0.
0.	0.	9102.8365	0.	0.
0.	0.	9102.8365	0.	0.
22.0000	0.	30.0000	140.0000	0.
0.	0.	9102.8365	0.	0.
0.	0.	9102.8365	0.	0.
23.0000	2.0000	500.0000	467.0000	449.0000
0.	0.	1707.8826	1699.3857	0.
8.4969	0.	0.	0.	0.
24.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
25.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
26.0000	1.0000	15.0000	70.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
27.0000	0.	30.0000	335.0000	1205.0000
0.	0.	359.7933	0.	359.7933
0.	0.	0.	0.	0.
28.0000	0.	30.0000	250.0000	219.0000
0.	0.	359.7933	0.	359.7933
0.	0.	0.	0.	0.

Figure B1. Contd.

29.0000	1.0000	15.0000	80.0000	0.
0.	0.	172738.7773	0.	0.
0.	172738.7773	0.	0.	0.
30.0000	0.	15.0000	80.0000	0.
0.	300.0000	172738.7773	0.	0.
0.	172738.7773	0.	0.	0.
31.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2604.7946	0.	2604.7946
0.	0.	0.	0.	0.
32.0000	0.	30.0000	250.0000	1079.6000
0.	0.	2604.7946	0.	2604.7946
0.	0.	0.	0.	0.
33.0000	2.0000	15.0000	1967.0787	0.
0.	0.	183296.9961	0.	0.
0.	0.	0.	183296.9961	0.
34.0000	0.	500.0000	467.0000	1205.0000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
35.0000	0.	15.0000	3000.0000	0.
0.	0.	183296.9961	0.	0.
0.	0.	0.	183296.9961	0.
36.0000	1.0000	15.0000	70.0000	38.0000
0.	0.	509.8157	509.8157	0.
0.	0.	0.	0.	0.

CONDENSER SURFACE AREA REQUIRED = 5650.75SQ. FT.

ECONOMIZER SURFACE AREA REQUIRED = 55.81SQ. FT.

Figure B1. Contd.

STREAM VARIABLES MATRIX AT RUN 1 LOOP 3

1.0000	0.	500.0000	630.0000	1344.0000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
2.0000	0.	2.0000	126.0000	1011.2000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
3.0000	1.0000	15.0000	80.0000	49.0000
0.	0.	8.4969	0.	0.
8.4969	0.	0.	0.	0.
4.0000	2.0000	15.0000	126.0000	94.0000
0.	0.	509.8157	0.	509.8157
0.	0.	0.	0.	0.
5.0000	0.	2.0000	126.0000	94.0000
62.4000	0.	171646.4492	171637.9512	0.
8.4969	0.	0.	0.	0.
6.0000	0.	30.0000	70.0000	0.
0.	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
7.0000	2.0000	30.0000	95.0000	0.
0.	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
8.0000	1.0000	15.0000	70.0000	0.
64.0000	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
9.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2041.6575	0.	2041.6575
0.	0.	0.	0.	0.
10.0000	0.	30.0000	250.0000	1058.7000
0.	0.	2041.6575	0.	2041.6575
0.	0.	0.	0.	0.
11.0000	0.	30.0000	126.0000	94.0831
62.4000	0.	171646.4492	171637.9512	0.
8.4969	0.	0.	0.	0.
12.0000	0.	500.0000	467.0000	1205.0000
0.	0.	104.7822	0.	104.7822
0.	0.	0.	0.	0.
13.0000	0.	30.0000	250.0000	1058.7000
0.	0.	104.7822	0.	104.7822
0.	0.	0.	0.	0.
14.0000	0.	30.0000	161.8737	129.9568

Figure B1. Contd.

62.4000	0.	178543.1562	178534.6582	0.
8.4969	0.	0.	0.	0.
15.0000	0.	500.0000	161.8737	131.3516
62.4000	0.	178543.1562	178534.6582	0.
8.4969	0.	0.	0.	0.
16.0000	0.	500.0000	467.0000	1205.0000
0.	0.	1829.5135	0.	1829.5135
0.	0.	0.	0.	0.
17.0000	0.	30.0000	250.0000	1058.7000
0.	0.	1829.5135	0.	1829.5135
0.	0.	0.	0.	0.
18.0000	0.	500.0000	367.0000	339.0000
0.	0.	178543.1562	178534.6582	0.
8.4969	0.	0.	0.	0.
19.0000	0.	500.0000	467.0000	1205.0000
0.	0.	172557.9062	0.	172557.9062
0.	0.	0.	0.	0.
20.0000	0.	30.0000	140.0000	0.
0.	0.	9218.7312	0.	0.
0.	0.	9218.7312	0.	0.
21.0000	1.0000	15.0000	70.0000	0.
0.	0.	9218.7312	0.	0.
0.	0.	9218.7312	0.	0.
22.0000	0.	30.0000	140.0000	0.
0.	0.	9218.7312	0.	0.
0.	0.	9218.7312	0.	0.
23.0000	2.0000	500.0000	467.0000	449.0000
0.	0.	1707.8826	1699.3857	0.
8.4969	0.	0.	0.	0.
24.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
25.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
26.0000	1.0000	15.0000	70.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
27.0000	0.	30.0000	335.0000	1205.0000
0.	0.	363.7427	0.	363.7427
0.	0.	0.	0.	0.
28.0000	0.	30.0000	250.0000	219.0000
0.	0.	363.7427	0.	363.7427
0.	0.	0.	0.	0.

Figure B1. Contd.

29.0000	1.0000	15.0000	80.0000	0.
0.	0.	174634.8828	0.	0.
0.	174634.8828	0.	0.	0.
30.0000	0.	15.0000	80.0000	0.
0.	300.0000	174634.8828	0.	0.
0.	174634.8828	0.	0.	0.
31.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2633.3867	0.	2633.3867
0.	0.	0.	0.	0.
32.0000	0.	30.0000	250.0000	1079.6000
0.	0.	2633.3867	0.	2633.3867
0.	0.	0.	0.	0.
33.0000	2.0000	15.0000	2011.8155	0.
0.	0.	185308.9961	0.	0.
0.	0.	0.	185308.9961	0.
34.0000	0.	500.0000	467.0000	1205.0000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
35.0000	0.	15.0000	3000.0000	0.
0.	0.	185308.9961	0.	0.
0.	0.	0.	185308.9961	0.
36.0000	1.0000	15.0000	70.0000	38.0000
0.	0.	2209.2014	2209.2014	0.
0.	0.	0.	0.	0.

CONDENSER SURFACE AREA REQUIRED = 5650.75SQ. FT.

ECONOMIZER SURFACE AREA REQUIRED = 55.39SQ. FT.

Figure B1. Contd.

STREAM VARIABLES MATRIX AT RUN 1 LOOP 4

1.0000	0.	500.0000	680.0000	1344.0000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
2.0000	0.	2.0000	126.0000	1011.2000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
3.0000	1.0000	15.0000	80.0000	49.0000
0.	0.	8.4969	0.	0.
8.4969	0.	0.	0.	0.
4.0000	2.0000	15.0000	126.0000	94.0000
0.	0.	509.8157	0.	509.8157
0.	0.	0.	0.	0.
5.0000	0.	2.0000	126.0000	94.0000
62.4000	0.	171646.4492	171637.9512	0.
8.4969	0.	0.	0.	0.
6.0000	0.	30.0000	70.0000	0.
0.	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
7.0000	2.0000	30.0000	95.0000	0.
0.	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
8.0000	1.0000	15.0000	70.0000	0.
64.0000	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
9.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2041.6575	0.	2041.6575
0.	0.	0.	0.	0.
10.0000	0.	30.0000	250.0000	1058.7000
0.	0.	2041.6575	0.	2041.6575
0.	0.	0.	0.	0.
11.0000	0.	30.0000	126.0000	94.0831
62.4000	0.	171646.4492	171637.9512	0.
8.4969	0.	0.	0.	0.
12.0000	0.	500.0000	467.0000	1205.0000
0.	0.	104.7822	0.	104.7822
0.	0.	0.	0.	0.
13.0000	0.	30.0000	250.0000	1058.7000
0.	0.	104.7822	0.	104.7822
0.	0.	0.	0.	0.
14.0000	0.	30.0000	162.2556	130.3387

Figure B1 Contd.

62.4000	0.	178619.5254	178611.0273	0.
8.4969	0.	0.	0.	0.
15.0000	0.	500.0000	162.2556	131.7335
62.4000	0.	178619.5254	178611.0273	0.
8.4969	0.	0.	0.	0.
16.0000	0.	500.0000	467.0000	1205.0000
0.	0.	1830.2961	0.	1830.2961
0.	0.	0.	0.	0.
17.0000	0.	30.0000	250.0000	1058.7000
0.	0.	1830.2961	0.	1830.2961
0.	0.	0.	0.	0.
18.0000	0.	500.0000	367.0000	339.0000
0.	0.	178619.5254	178611.0273	0.
8.4969	0.	0.	0.	0.
19.0000	0.	500.0000	467.0000	1205.0000
0.	0.	176835.2734	0.	176835.2734
0.	0.	0.	0.	0.
20.0000	0.	30.0000	140.0000	0.
0.	0.	9446.9573	0.	0.
0.	0.	9446.9573	0.	0.
21.0000	1.0000	15.0000	70.0000	0.
0.	0.	9446.9573	0.	0.
0.	0.	9446.9573	0.	0.
22.0000	0.	30.0000	140.0000	0.
0.	0.	9446.9573	0.	0.
0.	0.	9446.9573	0.	0.
23.0000	2.0000	500.0000	467.0000	449.0000
0.	0.	1707.8826	1699.3857	0.
8.4969	0.	0.	0.	0.
24.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
25.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
26.0000	1.0000	15.0000	70.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
27.0000	0.	30.0000	335.0000	1205.0000
0.	0.	371.5199	0.	371.5199
0.	0.	0.	0.	0.
28.0000	0.	30.0000	250.0000	219.0000
0.	0.	371.5199	0.	371.5199
0.	0.	0.	0.	0.

Figure B1. Contd.

29.0000	1.0000	15.0000	80.0000	0.
0.	0.	178368.7988	0.	0.
0.	178368.7988	0.	0.	0.
30.0000	0.	15.0000	80.0000	0.
0.	300.0000	178368.7988	0.	0.
0.	178368.7988	0.	0.	0.
31.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2689.6919	0.	2689.6919
0.	0.	0.	0.	0.
32.0000	0.	30.0000	250.0000	1079.6000
0.	0.	2689.6919	0.	2689.6919
0.	0.	0.	0.	0.
33.0000	2.0000	15.0000	2033.8900	0.
0.	0.	189271.1387	0.	0.
0.	0.	0.	189271.1387	0.
34.0000	0.	500.0000	467.0000	1205.0000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
35.0000	0.	15.0000	3000.0000	0.
0.	0.	189271.1387	0.	0.
0.	0.	0.	189271.1387	0.
36.0000	1.0000	15.0000	70.0000	38.0000
0.	0.	2209.2014	2209.2014	0.
0.	0.	0.	0.	0.

CONDENSER SURFACE AREA REQUIRED = 5650.7550. FT.

ECONOMIZER SURFACE AREA REQUIRED = 55.3150. FT.

Figure B1 Contd.

STREAM VARIABLES MATRIX AT RUN 1 LOOP 5

1.0000	0.	500.0000	680.0300	1344.0000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
2.0000	0.	2.0000	126.0000	1011.2000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
3.0000	1.0000	15.0000	80.0000	49.0000
0.	0.	8.4969	0.	0.
8.4969	0.	0.	0.	0.
4.0000	2.0000	15.0000	126.0000	94.0000
0.	0.	509.8157	0.	509.8157
0.	0.	0.	0.	0.
5.0000	0.	2.0000	126.0000	94.0000
62.4000	0.	171646.4492	171637.9512	0.
8.4969	0.	0.	0.	0.
6.0000	0.	30.0000	70.0000	0.
0.	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
7.0000	2.0000	30.0000	95.0000	0.
0.	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
8.0000	1.0000	15.0000	70.0000	0.
64.0000	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
9.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2041.6575	0.	2041.6575
0.	0.	0.	0.	0.
10.0000	0.	30.0000	250.0000	1058.7000
0.	0.	2041.6575	0.	2041.6575
0.	0.	0.	0.	0.
11.0000	0.	30.0000	126.0000	94.0831
62.4000	0.	171646.4492	171637.9512	0.
8.4969	0.	0.	0.	0.
12.0000	0.	500.0000	467.0000	1205.0000
0.	0.	104.7822	0.	104.7822
0.	0.	0.	0.	0.
13.0000	0.	30.0000	250.0000	1058.7000
0.	0.	104.7822	0.	104.7822
0.	0.	0.	0.	0.
14.0000	0.	30.0000	162.5626	130.6457

Figure B1. Contd.

62.4000	0.	178684.3926	178675.8945	0.
8.4969	0.	0.	0.	0.
15.0000	0.	500.0000	162.5626	132.0406
62.4000	0.	178684.3926	178675.8945	0.
8.4969	0.	0.	0.	0.
16.0000	0.	500.0000	467.0000	1205.0000
0.	0.	1830.9607	0.	1830.9607
0.	0.	0.	0.	0.
17.0000	0.	30.0000	250.0000	1058.7000
0.	0.	1830.9607	0.	1830.9607
0.	0.	0.	0.	0.
18.0000	0.	500.0000	367.0000	339.0000
0.	0.	178684.3926	178675.8945	0.
8.4969	0.	0.	0.	0.
19.0000	0.	500.0000	467.0000	1205.0000
0.	0.	176911.6426	0.	176911.6426
0.	0.	0.	0.	0.
20.0000	0.	30.0000	140.0000	0.
0.	0.	9451.0320	0.	0.
0.	0.	9451.0320	0.	0.
21.0000	1.0000	15.0000	70.0000	0.
0.	0.	9451.0320	0.	0.
0.	0.	9451.0320	0.	0.
22.0000	0.	30.0000	140.0000	0.
0.	0.	9451.0320	0.	0.
0.	0.	9451.0320	0.	0.
23.0000	2.0000	500.0000	467.0000	449.0000
0.	0.	1707.8826	1699.3857	0.
8.4969	0.	0.	0.	0.
24.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
25.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
26.0000	1.0000	15.0000	70.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
27.0000	0.	30.0000	335.0000	1205.0000
0.	0.	371.6588	0.	371.6588
0.	0.	0.	0.	0.
28.0000	0.	30.0000	250.0000	219.0000
0.	0.	371.6588	0.	371.6588
0.	0.	0.	0.	0.

Figure B1. Contd.

```
  29.0000       1.0000        15.0000        80.0000        0.
   0.           0.        178435.4629         0.            0.
   0.       178435.4629        0.             0.            0.

  30.0000       0.            15.0000        80.0000        0.
   0.         300.0000    178435.4629         0.            0.
   0.       178435.4629        0.             0.            0.

  31.0000       0.           500.0000       467.0000     1205.0000
   0.           0.          2690.6971         0.         2690.6971
   0.           0.             0.             0.            0.

  32.0000       0.            30.0000       250.0000     1079.6000
   0.           0.          2690.6971         0.         2690.6971
   0.           0.             0.             0.            0.

  33.0000       2.0000        15.0000      2035.3490        0.
   0.           0.        189341.8770         0.            0.
   0.           0.             0.        189341.8770        0.

  34.0000       0.           500.0000       467.0000     1205.0000
   0.           0.        169938.5684         0.       169938.5684
   0.           0.             0.             0.            0.

  35.0000       0.            15.0000      3000.0000        0.
   0.           0.        189341.8770         0.            0.
   0.           0.             0.        189341.8770        0.

  36.0000       1.0000        15.0000        70.0000       38.0000
   0.           0.          2209.2014      2209.2014        0.
   0.           0.             0.             0.            0.


   CONVERGENCE OBTAINED AFTER LOOP NUMBER    5


TRIAL AND ERROR ITERATIVE CALCULATIONS SUCCESSFUL IN    5 LOOPS.
```

Figure B1. Contd.

EQUIPMENT PARAMETERS MATRIX RUN 1 - FINAL

1.0000	0.	20000.0000	928.0000	80.0000
90.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
2.0000	0.	0.0001	0.0030	0.9700
650.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
3.0000	0.	70.0000	93.0000	996.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
4.0000	0.	70.0000	93.0000	996.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
5.0000	0.	1.0000	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
6.0000	0.	70.0000	93.0000	996.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
7.0000	0.	300.0000	1.0000	0.2000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
8.0000	0.	0.8800	0.1200	0.
0.	200.0000	80.0000	449.4000	0.
0.	0.	0.	0.	0.
9.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
10.0000	0.	0.8800	0.1200	0.
0.	0.	80.0000	0.	0.
0.	0.	0.	0.	0.
11.0000	0.	0.4800	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
12.0000	0.	60.0000	95.0000	4.0000
45.0000	32.0000	26.0000	115.0000	109.0000
996.0000	0.	0.	0.	0.
13.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.

Figure B1. Contd

STREAM VARIABLES MATRIX RUN 1 - FINAL

1,0000	0,	500,0000	680,0000	1344,0000
0,	0,	169938,5684	0,	169938,5684
0,	0,	0,	0,	0,
2,0000	0,	2,0000	126,0000	1011,2000
0,	0,	169938,5684	0,	169938,5684
0,	0,	0,	0,	0,
3,0000	1,0000	15,0000	80,0000	49,0000
0,	0,	8,4969	0,	0,
8,4969	0,	0,	0,	0,
4,0000	2,0000	15,0000	126,0000	94,0000
0,	0,	509,8157	0,	509,8157
0,	0,	0,	0,	0,
5,0000	0,	2,0000	126,0000	94,0000
62,4000	0,	171646,4492	171637,9512	0,
8,4969	0,	0,	0,	0,
6,0000	0,	30,0000	70,0000	0,
0,	0,	6403132,0000	0,	0,
0,	0,	0,	0,	6403132,0000
7,0000	2,0000	30,0000	95,0000	0,
0,	0,	6403132,0000	0,	0,
0,	0,	0,	0,	6403132,0000
8,0000	1,0000	15,0000	70,0000	0,
64,0000	0,	6403132,0000	0,	0,
0,	0,	0,	0,	6403132,0000
9,0000	0,	500,0000	467,0000	1205,0000
0,	0,	2041,6575	0,	2041,6575
0,	0,	0,	0,	0,
10,0000	0,	30,0000	250,0000	1058,7000
0,	0,	2041,6575	0,	2041,6575
0,	0,	0,	0,	0,
11,0000	0,	30,0000	126,0000	94,0831
62,4000	0,	171646,4492	171637,9512	0,
8,4969	0,	0,	0,	0,
12,0000	0,	500,0000	467,0000	1205,0000
0,	0,	104,7822	0,	104,7822
0,	0,	0,	0,	0,
13,0000	0,	30,0000	250,0000	1058,7000
0,	0,	104,7822	0,	104,7822
0,	0,	0,	0,	0,
14,0000	0,	30,0000	162,5626	130,6457
62,4000	0,	178684,3926	178675,8945	0,
8,4969	0,	0,	0,	0,
15,0000	0,	500,0000	162,5626	132,0406

Figure B1 Contd

62.4000	0.	178684.3926	178675.8945	0.
8.4969	0.	0.	0.	0.
16.0000	0.	500.0000	467.0000	1205.0000
0.	0.	1830.9607	0.	1830.9607
0.	0.	0.	0.	0.
17.0000	0.	30.0000	250.0000	1058.7000
0.	0.	1830.9607	0.	1830.9607
0.	0.	0.	0.	0.
18.0000	0.	500.0000	367.0000	339.0000
0.	0.	178684.3926	178675.8945	0.
8.4969	0.	0.	0.	0.
19.0000	0.	500.0000	467.0000	1205.0000
0.	0.	176911.6426	0.	176911.6426
0.	0.	0.	0.	0.
20.0000	0.	30.0000	140.0000	0.
0.	0.	9451.0320	0.	0.
0.	0.	9451.0320	0.	0.
21.0000	1.0000	15.0000	70.0000	0.
0.	0.	9451.0320	0.	0.
0.	0.	9451.0320	0.	0.
22.0000	0.	30.0000	140.0000	0.
0.	0.	9451.0320	0.	0.
0.	0.	9451.0320	0.	0.
23.0000	2.0000	500.0000	467.0000	449.0000
0.	0.	1707.8824	1629.3457	0.
8.4969	0.	0.	0.	0.
24.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
25.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
26.0000	1.0000	15.0000	70.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
27.0000	0.	30.0000	335.0000	1205.0000
0.	0.	371.6588	0.	371.6588
0.	0.	0.	0.	0.
28.0000	0.	30.0000	250.0000	219.0000
0.	0.	371.6588	0.	371.6588
0.	0.	0.	0.	0.
29.0000	1.0000	15.0000	80.0000	0.
0.	0.	178435.1629	0.	0.
0.	178435.4429	0.	0.	0.

Figure B1. Contd.

30.0000	0.	15.0000	80.0000	0.
0.	300.0000	178435.4629	0.	0.
0.	178435.4629	0.	0.	0.
31.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2690.6971	0.	2690.6971
0.	0.	0.	0.	0.
32.0000	0.	30.0000	250.0000	1079.6000
0.	0.	2690.6971	0.	2690.6971
0.	0.	0.	0.	0.
33.0000	2.0000	15.0000	2035.3490	0.
0.	0.	189341.8770	0.	0.
0.	0.	0.	189341.8770	0.
34.0000	0.	500.0000	467.0000	1205.0000
0.	0.	169938.5684	0.	169938.5694
-0.	0.	0.	0.	0.
35.0000	0.	15.0000	3000.0000	0.
0.	0.	189341.8770	0.	0.
0.	0.	0.	189341.8770	0.
36.0000	1.0000	15.0000	70.0000	38.0000
0.	0.	2209.2114	2209.2014	0.
0.	0.	0.	0.	0.

Figure B1. Contd.

EQUIPMENT PARAMETERS MATRIX   RUN   2 - FINAL

1.0000	0.	20000.0000	850.0000	80.0000
90.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
2.0000	0.	0.0001	0.0030	0.9700
650.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
3.0000	0.	70.0000	93.0000	996.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
4.0000	0.	70.0000	93.0000	996.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
5.0000	0.	1.0000	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
6.0000	0.	70.0000	93.0000	996.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
7.0000	0.	300.0000	1.0000	1.2000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
8.0000	0.	0.8600	0.1200	0.
0.	200.0000	80.0000	449.4100	0.
0.	0.	0.	0.	0.
9.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
11.0000	0.	0.4800	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
12.0000	0.	60.0000	95.0000	4.0000
45.0000	32.0000	26.0000	115.0000	109.0000
996.0000	0.	0.	0.	0.
13.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.

Figure B2. Computer Calculations for Run 02 - Basic System Without Superheater, Order of Calculations Specified

STREAM VARIABLES MATRIX RUN 2 - FINAL

1.0000	0.	500.0000	467.0000	1205.0000
0.	0.	199139.2793	0.	199139.2793
0.	0.	0.	0.	0.
2.0000	0.	2.0000	126.0000	921.0000
0.	0.	199139.2793	0.	199139.2793
0.	0.	0.	0.	0.
3.0000	1.0000	15.0000	80.0000	49.0000
0.	0.	9.9570	0.	0.
9.9570	0.	0.	0.	0.
4.0000	2.0000	15.0000	126.0000	94.0000
0.	0.	597.4178	0.	597.4178
0.	0.	0.	0.	0.
5.0000	0.	2.0000	126.0000	94.0000
62.4000	0.	201140.6289	201130.6719	0.
9.9570	0.	0.	0.	0.
6.0000	0.	30.0000	70.0000	0.
0.	0.	6764894.6250	0.	0.
0.	0.	0.	0.	6764894.6250
7.0000	2.0000	30.0000	95.0000	0.
0.	0.	6764894.6250	0.	0.
0.	0.	0.	0.	6764894.6250
8.0000	1.0000	15.0000	70.0000	0.
64.0000	0.	6764894.6250	0.	0.
0.	0.	0.	0.	6764894.6250
9.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2157.0065	0.	2157.0065
0.	0.	0.	0.	0.
10.0000	0.	30.0000	250.0000	1058.7000
0.	0.	2157.0065	0.	2157.0065
0.	0.	0.	0.	0.
11.0000	0.	30.0000	126.0000	94.0831
62.4000	0.	201140.6289	201130.6719	0.
9.9570	0.	0.	0.	0.
12.0000	0.	500.0000	467.0000	1205.0000
0.	0.	122.7870	0.	122.7870
0.	0.	0.	0.	0.
13.0000	0.	30.0000	250.0000	1058.7000
0.	0.	122.7870	0.	122.7870
0.	0.	0.	0.	0.
14.0000	0.	30.0000	159.4998	127.5829
62.4000	0.	208655.1992	208645.2422	0.
9.9570	0.	0.	0.	0.
15.0000	0.	500.0000	159.4998	128.9777

Figure B2. Contd

62.4000	0.	208655.1992	208645.2422	0.
9.9570	0.	0.	0.	0.
16.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2138.0685	0.	2138.0685
0.	0.	0.	0.	0.
17.0000	0.	30.0000	250.0000	1058.7000
0.	0.	2138.0685	0.	2138.0685
0.	0.	0.	0.	0.
18.0000	0.	500.0000	367.0000	339.0000
0.	0.	208655.1992	208645.2422	0.
9.9570	0.	0.	0.	0.
19.0000	0.	500.0000	467.0000	1205.0000
0.	0.	206578.0391	0.	206578.0391
0.	0.	0.	0.	0.
20.0000	0.	30.0000	140.0000	0.
0.	0.	11035.9282	0.	0.
0.	0.	11035.9282	0.	0.
21.0000	1.0000	15.0000	70.0000	0.
0.	0.	11035.9282	0.	0.
0.	0.	11035.9282	0.	0.
22.0000	0.	30.0000	140.0000	0.
0.	0.	11035.9282	0.	0.
0.	0.	11035.9282	0.	0.
23.0000	2.0000	500.0000	467.0000	449.0000
0.	0.	2001.3497	1991.3928	0.
9.9570	0.	0.	0.	0.
24.0000	2.0000	30.0000	140.0000	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
25.0000	1.0000	30.0000	140.0000	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
26.0000	1.0000	15.0000	70.0000	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
27.0000	0.	30.0000	335.0000	1205.0000
0.	0.	376.0722	0.	376.0722
0.	0.	0.	0.	0.
28.0000	0.	30.0000	250.0000	219.0000
0.	0.	376.0722	0.	376.0722
0.	0.	0.	0.	0.
29.0000	1.0000	15.0000	80.0000	0.
0.	0.	180554.3633	0.	0.
0.	180554.3633	0.	0.	0.

Figure B2. Contd.

30.0000	0.	15.0000	80.0000	0.
0.	300.0000	180554.3633	0.	0.
0.	180554.3633	0.	0.	0.
31.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2722.6488	0.	2722.6488
0.	0.	0.	0.	0.
32.0000	0.	30.0000	250.0000	1079.6000
0.	0.	2722.6498	0.	2722.6498
0.	0.	0.	0.	0.
33.0000	2.0000	15.0000	1870.0889	0.
0.	0.	191590.2910	0.	0.
0.	0.	0.	191590.2910	0.
35.0000	0.	15.0000	3000.0000	0.
0.	0.	191590.2910	0.	0.
0.	0.	0.	191590.2910	0.
36.0000	1.0000	15.0000	70.0000	38.0000
0.	0.	2588.8106	2598.8106	0.
0.	0.	0.	0.	0.

Figure B2. Contd

EQUIPMENT PARAMETERS MATRIX RUN 2 - FINAL

1.0000	0.	20000.0000	850.0000	80.0000
90.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
2.0000	0.	0.0001	0.0030	0.9700
650.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
3.0000	0.	70.0000	93.0000	996.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
4.0000	0.	70.0000	93.0000	996.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
5.0000	0.	1.0000	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
6.0000	0.	70.0000	93.0000	996.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
7.0000	0.	300.0000	1.0000	0.2000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
8.0000	0.	0.8800	0.1200	0.
0.	200.0000	80.0000	449.4000	0.
0.	0.	0.	0.	0.
9.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
11.0000	0.	0.4800	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
12.0000	0.	60.0000	95.0000	4.0000
45.0000	32.0000	26.0000	115.0000	109.0000
996.0000	0.	0.	0.	0.
13.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.

Figure B3. Computer Calculations for Run 02 - Basic System Without Superheater, Order of Calculations Not Specified

STREAM VARIABLES MATRIX RUN 2 - FINAL

1.0000	0.	500.0000	467.0000	1205.0000
0.	0.	199139.2793	0.	199139.2793
0.	0.	0.	0.	0.
2.0000	0.	2.0000	126.0000	921.0000
0.	0.	199139.2793	0.	199139.2793
0.	0.	0.	0.	0.
3.0000	1.0000	15.0000	80.0000	49.0000
0.	0.	9.9570	0.	0.
9.9570	0.	0.	0.	0.
4.0000	2.0000	15.0000	126.0000	94.0000
0.	0.	597.4178	0.	597.4178
0.	0.	0.	0.	0.
5.0000	0.	2.0000	126.0000	94.0000
62.4000	0.	201140.6289	201130.6719	0.
9.9570	0.	0.	0.	0.
6.0000	0.	30.0000	70.0000	0.
0.	0.	6764894.6250	0.	0.
0.	0.	0.	0.	6764894.6250
7.0000	2.0000	30.0000	95.0000	0.
0.	0.	6764894.6250	0.	0.
0.	0.	0.	0.	6764894.6250
8.0000	1.0000	15.0000	70.0000	0.
64.0000	0.	6764894.6250	0.	0.
0.	0.	0.	0.	6764894.6250
9.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2157.0065	0.	2157.0065
0.	0.	0.	0.	0.
10.0000	0.	30.0000	250.0000	1058.7000
0.	0.	2157.0065	0.	2157.0065
0.	0.	0.	0.	0.
11.0000	0.	30.0000	126.0000	94.0831
62.4000	0.	201140.6289	201130.6719	0.
9.9570	0.	0.	0.	0.
12.0000	0.	500.0000	467.0000	1205.0000
0.	0.	122.7870	0.	122.7870
0.	0.	0.	0.	0.
13.0000	0.	30.0000	250.0000	1058.7000
0.	0.	122.7870	0.	122.7870
0.	0.	0.	0.	0.
14.0000	0.	30.0000	159.5004	127.5835
62.4000	0.	208655.3184	208645.3613	0.
9.9570	0.	0.	0.	0.
15.0000	0.	500.0000	159.5004	128.9783

Figure B3. Contd

62.4000	0.	208655.3184	208645.3613	0.
9.9570	0.	0.	0.	0.
16.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2138.0697	0.	2138.0697
0.	0.	0.	0.	0.
17.0000	0.	30.0000	250.0000	1058.7000
0.	0.	2138.0697	0.	2138.0697
0.	0.	0.	0.	0.
18.0000	0.	500.0000	367.0000	339.0000
0.	0.	208555.3184	208645.3613	0.
9.9570	0.	0.	0.	0.
19.0000	0.	500.0000	467.0000	1205.0000
0.	0.	206607.4336	0.	206607.4336
0.	0.	0.	0.	0.
20.0000	0.	30.0000	140.0000	0.
0.	0.	11037.4966	0.	0.
0.	0.	11037.4966	0.	0.
21.0000	1.0000	15.0000	70.0000	0.
0.	0.	11030.8942	0.	0.
0.	0.	11030.8942	0.	0.
22.0000	0.	30.0000	140.0000	0.
0.	0.	11037.4966	0.	0.
0.	0.	11037.4966	0.	0.
23.0000	2.0000	500.0000	467.0000	449.0000
0.	0.	2001.3497	1991.3928	0.
9.9570	0.	0.	0.	0.
24.0000	2.0000	30.0000	140.0000	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
25.0000	1.0000	30.0000	140.0000	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
26.0000	1.0000	15.0000	70.0000	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
27.0000	0.	30.0000	335.0000	1205.0000
0.	0.	375.9007	0.	375.9007
0.	0.	0.	0.	0.
28.0000	0.	30.0000	250.0000	219.0000
0.	0.	375.9007	0.	375.9007
0.	0.	0.	0.	0.
29.0000	1.0000	15.0000	60.0000	0.
0.	0.	180472.0039	0.	0.
0.	180472.0039	0.	0.	0.
30.0000	0.	15.0000	80.0000	0.
0.	300.0000	180472.0039	0.	0.
0.	180472.0039	0.	0.	0.
31.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2721.4069	0.	2721.4069
0.	0.	0.	0.	0.
32.0000	0.	30.0000	250.0000	1079.6000
0.	0.	2721.4069	0.	2721.4069
0.	0.	0.	0.	0.
33.0000	2.0000	15.0000	1869.6149	0.
0.	0.	191509.5000	0.	0.
0.	0.	0.	191509.5000	0.
35.0000	0.	15.0000	3000.0000	0.
0.	0.	191509.5000	0.	0.
0.	0.	0.	191509.5000	0.
36.0000	1.0000	15.0000	70.0000	38.0000
0.	0.	2588.8106	2588.8106	0.
0.	0.	0.	0.	0.

Figure B3. Contd.

13 EQUIPMENT INTERCONNECTED BY 36 STREAMS.

ITERATIVE CALCULATION-ASSUMED INPUT STREAMS ARE

19 18 17

13 EQUIPMENT CALCULATED IN THE ORDER

9 11 12 3 8 10 13 1 2 4
5 6 7

CONDENSER SURFACE AREA REQUIRED = 5654.21SQ. FT.

ECONOMIZER SURFACE AREA REQUIRED = 59.12SQ. FT.

STREAM VARIABLES MATRIX AT RUN 3 LOOP 1

1.0000	0.	500.0000	680.0000	1344.0000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
2.0000	0.	2.0000	126.0000	1011.2000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
3.0000	1.0000	15.0000	80.0000	49.0000
0.	0.	8.4969	0.	0.
8.4969	0.	0.	0.	0.
4.0000	2.0000	15.0000	126.0000	94.0000
0.	0.	509.8157	0.	509.8157
0.	0.	0.	0.	0.
5.0000	0.	2.0000	126.0000	94.0000
62.4000	0.	169947.0645	169938.5664	0.
8.4969	0.	0.	0.	0.
6.0000	0.	30.0000	70.0000	0.
0.	0.	6407056.3750	0.	0.
0.	0.	0.	0.	6407056.3750
7.0000	2.0000	30.0000	95.0000	0.
0.	0.	6407056.3750	0.	0.
0.	0.	0.	0.	6407056.3750
8.0000	1.0000	15.0000	70.0000	0.
64.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
9.0000	0.	500.0000	467.0000	1205.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
10.0000	0.	30.0000	250.0000	1058.7000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
11.0000	0.	30.0000	126.0000	94.0831
62.4000	0.	169947.0645	169938.5664	0.
8.4969	0.	0.	0.	0.
12.0000	0.	500.0000	467.0000	1205.0000
0.	0.	103.7448	0.	103.7448
0.	0.	0.	0.	0.
13.0000	0.	30.0000	250.0000	1058.7000
0.	0.	103.7448	0.	103.7448
0.	0.	0.	0.	0.
14.0000	0.	30.0000	143.0860	111.1691

Figure B4: Computer Calculations for Run 03 - Basic System, Order of Calculations Not Specified

62,4000	0.	172947,6699	172939.1719	0.
8,4969	0.	0.	0.	0.
15,0000	0.	500,0000	143.0860	112,5639
62,4000	0.	172947,6699	172939.1719	0.
8,4969	0.	0.	0.	0.
16,0000	0.	500,0000	467,0000	1205.0000
0.	0.	1772,1771	0.	1772.1771
0.	0.	0.	0.	0.
17,0000	0.	30,0000	250.0000	1058.7000
0.	0.	1772,1771	0.	1772.1771,
0.	0.	0.	0.	0.
18,0000	0.	500,0000	367.0000	339,0000
0.	0.	172947,6699	172939.1719	0.
8,4969	0.	0.	0.	0.
19.0000	0.	500.0000	467.0000	1205.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
20,0000	0.	30,0000	140.0000	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
21,0000	1,0000	15,0000	70.0000	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
22,0000	0.	30,0000	140.0000	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
23,0000	2,0000	500,0000	467.0000	449.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
24,0000	0.	30,0000	140.0000	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
25,0000	0.	30,0000	140.0000	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
26,0000	1.0000	15,0000	70.0000	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
27,0000	0.	30,0000	335.0000	1205.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
28,0000	0.	30.0000	250.0000	219.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.

Figure B4. Contd.

```
 29.0000        1.0000        15.0000        80.0000        0.
  0.            0.        192107.4102         0.            0.
  0.        192107.4102        0.             0.            0.

 30.0000        0.            15.0000        80.0000        0.
  0.          300.0000    192107.4102         0.            0.
  0.        192107.4102        0.             0.            0.

 31.0000        0.           500.0000       467.0000     1205.0000
  0.            0.          2896.8617         0.         2896.8617
  0.            0.             0.             0.            0.

 32.0000        0.            30.0000       250.0000     1079.6000
  0.            0.          2896.8617         0.         2896.8617
  0.            0.             0.             0.            0.

 33.0000        2.0000        15.0000      1992.0897        0.
  0.            0.        192107.4102         0.            0.
  0.            0.             0.        192107.4102        0.

 34.0000        0.           500.0000       467.0000     1205.0000
  0.            0.             0.             0.            0.
  0.            0.             0.             0.            0.

 35.0000        0.            15.0000      3000.0000        0.
  0.            0.        192107.4102         0.            0.
  0.            0.             0.        192107.4102        0.

 36.0000        1.0000        15.0000        70.0000       38.0000
  0.            0.           509.8157       509.8157        0.
  0.            0.             0.             0.            0.

CONDENSER SURFACE AREA REQUIRED =    5650.755Q. FT.
<*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*>
 TRACE OF CALLS IN REVERSE ORDER   ERROR NO. 10
    CALLING        ID      ABSOLUTE       ARGUMENT          ARGUMENT          ARGUMENT          ARGUMENT          ARGUMENT
    ROUTINE        #       LOCATION          #1                #2                #3                #4                #5
    ALOG10         36      027424     000000000012
    ECONFS          9      030417     775207753621
    FOCAL          25      044210
    ......         90      044752
 LOG(-B) NOT ALLOWED
 EVALUATE FOR +B
<*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*>

 ECONOMIZER SURFACE AREA REQUIRED =    -11.845Q. FT.
```

Figure B4. Contd

STREAM VARIABLES MATRIX AT RUN 3 LOOP 2

1.0000	0.	500.0000	680.0000	1344.0000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
2.0000	0.	2.0000	126.0000	1011.2000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
3.0000	1.0000	15.0000	80.0000	42.0000
0.	0.	8.4969	0.	0.
8.4969	0.	0.	0.	0.
4.0000	2.0000	15.0000	126.0000	94.0000
0.	0.	509.8157	0.	509.8157
0.	0.	0.	0.	0.
5.0000	0.	2.0000	126.0000	94.0000
62.4000	0.	171646.4492	171637.9512	0.
8.4969	0.	0.	0.	0.
6.0000	0.	30.0000	70.0000	0.
0.	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
7.0000	2.0000	30.0000	95.0000	0.
0.	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
8.0000	1.0000	15.0000	70.0000	0.
64.0000	0.	6407056.3750	0.	0.
0.	0.	0.	0.	6407056.3750
9.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2042.9088	0.	2042.9088
0.	0.	0.	0.	0.
10.0000	0.	30.0000	250.0000	1058.7000
0.	0.	2042.9088	0.	2042.9088
0.	0.	0.	0.	0.
11.0000	0.	30.0000	126.0000	94.0831
62.4000	0.	171646.4492	171637.9512	0.
8.4969	0.	0.	0.	0.
12.0000	0.	500.0000	467.0000	1205.0000
0.	0.	104.7822	0.	104.7822
0.	0.	0.	0.	0.
13.0000	0.	30.0000	250.0000	1058.7000
0.	0.	104.7822	0.	104.7822
0.	0.	0.	0.	0.
14.0000	0.	30.0000	147.5370	115.6201

Figure B4. Contd.

62.4000	0.	175566.3145	175557.8164	0.
8.4969	0.	0.	0.	0.
15.0000	0.	500.0000	147.5370	117.0149
62.4000	0.	175566.3145	175557.8164	0.
8.4969	0.	0.	0.	0.
16.0000	0.	500.0000	467.0000	1205.0000
0.	0.	1799.0101	0.	1799.0101
0.	0.	0.	0.	0.
17.0000	0.	30.0000	250.0000	1058.7000
0.	0.	1799.0101	0.	1799.0101
0.	0.	0.	0.	0.
18.0000	0.	500.0000	367.0000	339.0000
0.	0.	175566.3145	175557.8164	0.
8.4969	0.	0.	0.	0.
19.0000	0.	500.0000	467.0000	1205.0000
0.	0.	171239.7871	0.	171239.7871
0.	0.	0.	0.	0.
20.0000	0.	30.0000	140.0000	0.
0.	0.	9148.4008	0.	0.
0.	0.	9148.4008	0.	0.
21.0000	1.0000	15.0000	70.0000	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
22.0000	0.	30.0000	140.0000	0.
0.	0.	9148.4008	0.	0.
0.	0.	9148.4008	0.	0.
23.0000	2.0000	500.0000	467.0000	449.0000
0.	0.	1707.8826	1699.3857	0.
8.4969	0.	0.	0.	0.
24.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
25.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
26.0000	1.0000	15.0000	70.0000	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
27.0000	0.	30.0000	335.0000	1205.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
28.0000	0.	30.0000	250.0000	219.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.

Figure B4. Contd

29.0000	1.0000	15.0000	80.0000	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
30.0000	0.	15.0000	80.0000	0.
0.	300.0000	0.	0.	0.
0.	0.	0.	0.	0.
31.0000	0.	500.0000	467.0000	1205.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
32.0000	0.	30.0000	250.0000	1079.6000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
33.0000	2.0000	15.0000	-15168.1882	0.
0.	0.	10603.7844	0.	0.
0.	0.	0.	10603.7844	0.
34.0000	0.	500.0000	467.0000	1205.0000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
35.0000	0.	15.0000	3000.0000	0.
0.	0.	10603.7844	0.	0.
0.	0.	0.	10603.7844	0.
36.0000	1.0000	15.0000	70.0000	38.0000
0.	0.	2209.2014	2209.2014	0.
0.	0.	0.	0.	0.

CONDENSER SURFACE AREA REQUIRED = 5650.755Q. FT.

ECONOMIZER SURFACE AREA REQUIRED = 55.865Q. FT.

Figure B4: Contd.

STREAM VARIABLES MATRIX AT RUN 3 LOOP 3

1.0000	0.	500.0000	680.0000	1344.0000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
2.0000	0.	2.0000	126.0000	1011.2000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
3.0000	1.0000	15.0000	80.0000	49.0000
0.	0.	8.4969	0.	0.
8.4969	0.	0.	0.	0.
-4.0000	2.0000	15.0000	126.0000	94.0000
0.	0.	509.8157	0.	509.8157
0.	0.	0.	0.	0.
5.0000	0.	2.0000	126.0000	94.0000
62.4000	0.	171646.4492	171637.9512	0.
8.4969	0.	0.	0.	0.
6.0000	0.	30.0000	70.0000	0.
0.	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
7.0000	2.0000	30.0000	95.0000	0.
0.	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
8.0000	1.0000	15.0000	70.0000	0.
64.0000	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
9.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2041.6575	0.	2041.6575
0.	0.	0.	0.	0.
10.0000	0.	30.0000	250.0000	1058.7000
0.	0.	2041.6575	0.	2041.6575
0.	0.	0.	0.	0.
11.0000	0.	30.0000	126.0000	94.0831
62.4000	0.	171646.4492	171637.9512	0.
8.4969	0.	0.	0.	0.
12.0000	0.	500.0000	467.0000	1205.0000
0.	0.	104.7822	0.	104.7822
0.	0.	0.	0.	0.
13.0000	0.	30.0000	250.0000	1058.7000
0.	0.	104.7822	0.	104.7822
0.	0.	0.	0.	0.
14.0000	0.	30.0000	162.0036	130.0867

Figure B4: Contd.

62.4000	0.	178569.2773	178560.7793	0.
8.4969	0.	0.	0.	0.
15.0000	0.	500.0000	162.0036	131.4815
62.4000	0.	178569.2773	178560.7793	0.
8.4969	0.	0.	0.	0.
16.0000	0.	500.0000	467.0000	1205.0000
0.	0.	1829.7812	0.	1829.7812
0.	0.	0.	0.	0.
17.0000	0.	30.0000	250.0000	1058.7000
0.	0.	1829.7812	0.	1829.7812
0.	0.	0.	0.	0.
18.0000	0.	500.0000	367.0000	339.0000
0.	0.	178569.2773	178560.7793	0.
8.4969	0.	0.	0.	0.
19.0000	0.	500.0000	467.0000	1205.0000
0.	0.	173858.4316	0.	173858.4315
0.	0.	0.	0.	0.
20.0000	0.	30.0000	140.0000	0.
0.	0.	9288.1228	0.	0.
0.	0.	9288.1228	0.	0.
21.0000	1.0000	15.0000	70.0000	0.
0.	0.	9148.4008	0.	0.
0.	0	9148.4008	0.	0.
22.0000	0.	30.0000	140.0000	0.
0.	0.	9288.1228	0.	0.
0.	0.	9288.1228	0.	0.
23.0000	2.0000	500.0000	467.0000	449.0000
0.	0.	1707.8826	1699.3857	0.
8.4969	0.	0.	0.	0.
24.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
25.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
26.0000	1.0000	15.0000	70.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
27.0000	0.	30.0000	335.0000	1205.0000
0.	0.	361.3460	0.	361.3460
0.	0.	0.	0.	0.
28.0000	0.	30.0000	250.0000	212.0000
0.	0.	361.3460	0.	361.3460
0.	0.	0.	0.	0.

Figure B4. Contd.

29.0000	1.0000	15.0000	80.0000	0.
0.	0.	173484.2363	0.	0.
0.	173484.2363	0.	0.	0.
30.0000	0.	15.0000	80.0000	0.
0.	300.0000	173484.2363	0.	0.
0.	173484.2363	0.	0.	0.
31.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2616.0356	0.	2616.0356
0.	0.	0.	0.	0.
32.0000	0.	30.0000	250.0000	1079.6000
0.	0.	2616.0356	0.	2616.0356
0.	0.	0.	0.	0.
33.0000	2.0000	15.0000	2006.4997	0.
0.	0.	184227.7422	0.	0.
0.	0.	0.	184227.7422	0.
34.0000	0.	500.0000	467.0000	1205.0000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
35.0000	0.	15.0000	3000.0000	0.
0.	0.	184227.7422	0.	0.
0.	0.	0.	184227.7422	0.
36.0000	1.0000	15.0000	70.0000	38.0000
0.	0.	2209.2014	2209.2014	0.
0.	0.	0.	0.	0.

CONDENSER SURFACE AREA REQUIRED = 5650.75SQ. FT.

ECONOMIZER SURFACE AREA REQUIRED = 55.58SQ. FT.

Figure B4: Contd

STREAM VARIABLES MATRIX AT RUN 3 LOOP 4

1,0000	0,	500,0000	680,0000	1344,0000
0,	0,	169938,5684	0,	169938,5684
0,	0,	0,	0,	0,
2,0000	0,	2,0000	126,0000	1011,2000
0,	0,	169938,5684	0,	169938,5684
0,	0,	0,	0,	0,
3,0000	1,0000	15,0000	80,0000	49,0000
0,	0,	8,4969	0,	0,
8,4969	0,	0,	0,	0,
4,0000	2,0000	15,0000	126,0000	94,0000
0,	0,	509,8157	0,	509,8157
0,	0,	0,	0,	0,
5,0000	0,	2,0000	126,0000	94,0000
62,4000	0,	171646,4492	171637,9512	0,
8,4969	0,	0,	0,	0,
6,0000	0,	30,0000	70,0000	0,
0,	0,	6403132,0000	0,	0,
0,	0,	0,	0,	6403132,0000
7,0000	2,0000	30,0000	95,0000	0,
0,	0,	6403132,0000	0,	0,
0,	0,	0,	0,	6403132,0000
8,0000	1,0000	15,0000	70,0000	0,
64,0000	0,	6403132,0000	0,	0,
0,	0,	0,	0,	6403132,0000
9,0000	0,	500,0000	467,0000	1205,0000
0,	0,	2041,6575	0,	2041,6575
0,	0,	0,	0,	0,
10,0000	0,	30,0000	250,0000	1058,7000
0,	0,	2041,6575	0,	2041,6575
0,	0,	0,	0,	0,
11,0000	0,	30,0000	126,0000	94,0831
62,4000	0,	171646,4492	171637,9512	0,
8,4969	0,	0,	0,	0,
12,0000	0,	500,0000	467,0000	1205,0000
0,	0,	104,7822	0,	104,7822
0,	0,	0,	0,	0,
13,0000	0,	30,0000	250,0000	1058,7000
0,	0,	104,7822	0,	104,7822
0,	0,	0,	0,	0,
14,0000	0,	30,0000	162,3491	130,4322

Figure B4. Contd

62,4000	0,	178639,2773	178630,7793	0,
8,4969	0,	0,	0,	0,
15,0000	0,	500,0000	162,3491	131,8270
62,4000	0,	178639,2773	178630,7793	0,
8,4969	0,	0,	0,	0,
16,0000	0,	500,0000	467,0000	1205,0000
0,	0,	1830,4984	0,	1830,4984
0,	0,	0,	0,	0,
17,0000	0,	30,0000	250,0000	1058,7000
0,	0,	1830,4984	0,	1830,4984
0,	0,	0,	0,	0,
18,0000	0,	500,0000	367,0000	339,0000
0,	0,	178639,2773	178630,7793	0,
8,4969	0,	0,	0,	0,
19,0000	0,	500,0000	467,0000	1205,0000
0,	0,	176861,3945	0,	176861,3945
0,	0,	0,	0,	0,
20,0000	0,	30,0000	140,0000	0,
0,	0,	9448,3510	0,	0,
0,	0,	9448,3510	0,	0,
21,0000	1,0000	15,0000	70,0000	0,
0,	0,	9288,1228	0,	0,
0,	0,	9288,1228	0,	0,
22,0000	0,	30,0000	140,0000	0,
0,	0,	9448,3510	0,	0,
0,	0,	9448,3510	0,	0,
23,0000	2,0000	500,0000	467,0000	449,0000
0,	0,	1707,8826	1699,3857	0,
8,4969	0,	0,	0,	0,
24,0000	0,	30,0000	140,0000	0,
0,	0,	1455,3838	0,	0,
0,	0,	1455,3838	0,	0,
25,0000	0,	30,0000	140,0000	0,
0,	0,	1455,3838	0,	0,
0,	0,	1455,3838	0,	0,
26,0000	1,0000	15,0000	70,0000	0,
0,	0,	1455,3838	0,	0,
0,	0,	1455,3838	0,	0,
27,0000	0,	30,0000	335,0000	1205,0000
0,	0,	366,1073	0,	366,1073
0,	0,	0,	0,	0,
28,0000	0,	30,0000	250,0000	219,0000
0,	0,	366,1073	0,	366,1073
0,	0,	0,	0,	0,

Figure B4. Contd.

29.0000	1.0000	15.0000	80.0000	0.
0.	0.	175770.1719	0.	0.
0.	175770.1719	0.	0.	0.
30.0000	0.	15.0000	80.0000	0.
0.	300.0000	175770.1719	0.	0.
0.	175770.1719	0.	0.	0.
31.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2650.5062	0.	2650.5062
0.	0.	0.	0.	0.
32.0000	0.	30.0000	250.0000	1079.6000
0.	0.	2650.5062	0.	2650.5062
0.	0.	0.	0.	0.
33.0000	2.0000	15.0000	2020.7875	0.
0.	0.	186673.9062	0.	0.
0.	0.	0.	186673.9062	0.
34.0000	0.	500.0000	467.0000	1205.0000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
35.0000	0.	15.0000	3000.0000	0.
0.	0.	186673.9062	0.	0.
0.	0.	0.	186673.9062	0.
36.0000	1.0000	15.0000	70.0000	38.0000
0.	0.	2209.2014	2209.2014	0.
0.	0.	0.	0.	0.

CONVERGENCE OBTAINED AFTER LOOP NUMBER 4

Figure B4. Contd.

EQUIPMENT PARAMETERS MATRIX RUN 3 - FINAL

1.0000	0.	20000.0000	928.0000	80.0000
90.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
2.0000	0.	0.0001	0.0030	0.9700
650.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
3.0000	0.	70.0000	93.0000	996.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
4.0000	0.	70.0000	93.0000	996.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
5.0000	0.	1.0000	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
6.0000	0.	70.0000	93.0000	996.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
7.0000	0.	300.0000	1.0000	0.2000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
8.0000	0.	0.8800	0.1200	0.
0.	200.0000	80.0000	449.4000	0.
0.	0.	0.	0.	0.
9.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
10.0000	0.	0.8800	0.1200	0.
0.	0.	80.0000	0.	0.
0.	0.	0.	0.	0.
11.0000	0.	0.4800	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
12.0000	0.	60.0000	95.0000	4.0000
45.0000	32.0000	26.0000	115.0000	109.0000
996.0000	0.	0.	0.	0.
13.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.

Figure B4. Contd.

STREAM VARIABLES MATRIX RUN 3 - FINAL

1,0000	0.	500,0000	680,0000	1344,0000
0,	0,	169938,5684	0,	169938,5684
0,	0,	0,	0,	0,
2,0000	0.	2,0000	126,0000	1011,2000
0,	0,	169938,5684	0,	169938,5684
0,	0,	0,	0,	0,
3,0000	1,0000	15,0000	80,0000	49,0000
0,	0,	8,4969	0,	0,
8,4969	0,	0,	0,	0,
4,0000	2,0000	15,0000	126,0000	94,0000
0,	0,	509,8157	0,	509,8157
0,	0,	0,	0,	0,
5,0000	0.	2,0000	126,0000	94,0000
62,4000	0.	171646,4492	171637,9512	0,
8,4969	0,	0,	0,	0,
6,0000	0.	30,0000	70,0000	0.
0.	0.	6403132,0000	0.	0,
0,	0,	0,	0,	6403132,0000
7,0000	2,0000	30,0000	95,0000	0,
0,	0,	6403132,0000	0,	0,
0,	0,	0,	0,	6403132,0000
8,0000	1,0000	15,0000	70,0000	0,
64,0000	0.	6403132,0000	0.	0,
0,	0,	0,	0,	6403132,0000
9,0000	0,	500,0000	467,0000	1205,0000
0,	0,	2041,6575	0,	2041,6575
0,	0,	0,	0,	0,
10,0000	0,	30,0000	250,0000	1058,7000
0,	0,	2041,6575	0,	2041,6575
0,	0,	0,	0,	0,
11,0000	0,	30,0000	126,0000	94,0631
62,4000	0,	171646,4492	171637,9512	0,
8,4969	0,	0,	0,	0,
12,0000	0,	500,0000	467,0000	1205,0000
0,	0,	104,7822	0.	104,7822
0,	0,	0,	0,	0,
13,0000	0,	30,0000	250,0000	1058,7000
0,	0,	104,7822	0,	104,7822
0,	0,	0,	0,	0,
14,0000	0,	30,0000	162,3491	130,4322
62,4000	0,	178639,2773	178630,7793	0,
8,4969	0,	0,	0,	0,
15,0000	0,	500,0000	162,3491	131,8270

Figure B4. Contd

62.4000	0.	178639.2773	178630.7793	0.
8.4969	0.	0.	0.	0.
16.0000	0.	500.0000	467.0000	1205.0000
0.	0.	1830.4984	0.	1830.4984
0.	0.	0.	0.	0.
17.0000	0.	30.0000	250.0000	1058.7000
0.	0.	1830.4984	0.	1830.4984
0.	0.	0.	0.	0.
18.0000	0.	500.0000	367.0000	339.0000
0.	0.	178639.2773	178630.7793	0.
8.4969	0.	0.	0.	0.
19.0000	0.	500.0000	467.0000	1205.0000
0.	0.	176861.3945	0.	176861.3945
0.	0.	0.	0.	0.
20.0000	0.	30.0000	140.0000	0.
0.	0.	9448.3510	0.	0.
0.	0.	9448.3510	0.	0.
21.0000	1.0000	15.0000	70.0000	0.
0.	0.	9288.1228	0.	0.
0.	0.	9288.1228	0.	0.
22.0000	0.	30.0000	140.0000	0.
0.	0.	9448.3510	0.	0.
0.	0.	9448.3510	0.	0.
23.0000	2.0000	500.0000	467.0000	449.0000
0.	0.	1707.8826	1699.3857	0.
8.4969	0.	0.	0.	0.
24.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
25.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
26.0000	1.0000	15.0000	70.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
27.0000	0.	30.0000	335.0000	1205.0000
0.	0.	366.1073	0.	366.1073
0.	0.	0.	0.	0.
28.0000	0.	30.0000	250.0000	219.0000
0.	0.	366.1073	0.	366.1073
0.	0.	0.	0.	0.
29.0000	1.0000	15.0000	80.0000	0.
0.	0.	175770.1719	0.	0.
0.	175770.1719	0.	0.	0.

Figure B4. Contd.

30.0000	0.	15.0000	80.0000	0.
0.	300.0000	175770.1719	0.	0.
0.	175770.1719	0.	0.	0.
31.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2650.5062	0.	2650.5062
0.	0.	0.	0.	0.
32.0000	0.	30.0000	250.0000	1079.6000
0.	0.	2650.5062	0.	2650.5062
0.	0.	0.	0.	0.
33.0000	2.0000	15.0000	2020.7876	0.
0.	0.	186673.9062	0.	0.
0.	0.	0.	186673.9062	0.
34.0000	0.	500.0000	467.0000	1205.0000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
35.0000	0.	15.0000	3000.0000	0.
0.	0.	186673.9062	0.	0.
0.	0.	0.	186673.9062	0.
36.0000	1.0000	15.0000	70.0000	38.0000
0.	0.	2209.2014	2209.2014	0.
0.	0.	0.	0.	0.

Figure B4. Contd.

EQUIPMENT PARAMETERS MATRIX RUN 4 - FINAL

1.0000	0.	20000.0000	928.0000	80.0000
90.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
2.0000	0.	0.0001	0.0030	0.9700
650.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
3.0000	0.	70.0000	93.0000	996.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
4.0000	0.	70.0000	93.0000	996.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
5.0000	0.	1.0000	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
6.0000	0.	70.0000	93.0000	996.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
8.0000	0.	0.8800	0.1200	0.
0.	200.0000	80.0000	449.4000	0.
0.	0.	0.	0.	0.
9.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
10.0000	0.	0.8800	0.1200	0.
0.	0.	80.0000	0.	0.
0.	0.	0.	0.	0.
11.0000	0.	0.4800	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
12.0000	0.	60.0000	95.0000	4.0000
45.0000	32.0000	26.0000	115.0000	109.0000
996.0000	0.	0.	0.	0.
13.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.

Figure B5. Computer Calculations for Run 04 - Basic System Without Economizer, Order of Calculations Specified

STREAM VARIABLES MATRIX RUN 4 - FINAL

1.0000	0.	500.0000	680.0000	1344.0000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
2.0000	0.	2.0000	126.0000	1011.2000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
3.0000	1.0000	15.0000	80.0000	49.0000
0.	0.	8.4969	0.	0.
8.4969	0.	0.	0.	0.
4.0000	2.0000	15.0000	126.0000	94.0000
0.	0.	509.8157	0.	509.8157
0.	0.	0.	0.	0.
5.0000	0.	2.0000	126.0000	94.0000
62.4000	0.	171646.4492	171637.9512	0.
8.4969	0.	0.	0.	0.
6.0000	0.	30.0000	70.0000	0.
0.	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
7.0000	2.0000	30.0000	95.0000	0.
0.	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
8.0000	1.0000	15.0000	70.0000	0.
64.0000	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
9.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2041.6575	0.	2041.6575
0.	0.	0.	0.	0.
10.0000	0.	30.0000	250.0000	1058.7000
0.	0.	2041.6575	0.	2041.6575
0.	0.	0.	0.	0.
11.0000	0.	30.0000	126.0000	94.0831
62.4000	0.	171646.4492	171637.9512	0.
8.4969	0.	0.	0.	0.
12.0000	0.	500.0000	467.0000	1205.0000
0.	0.	104.7822	0.	104.7822
0.	0.	0.	0.	0.
13.0000	0.	30.0000	250.0000	1058.7000
0.	0.	104.7822	0.	104.7822
0.	0.	0.	0.	0.
14.0000	0.	30.0000	165.6269	133.7100
62.4000	0.	179334.4922	179325.9941	0.
8.4969	0.	0.	0.	0.
15.0000	0.	500.0000	165.6269	135.1048

Figure B5. Contd

62.4000	0.	179334.4922	179325.9941	0.
8.4969	0.	0.	0.	0.
16.0000	0.	500.0000	467.0000	1205.0000
0.	0.	1837.6222	0.	1837.6222
0.	0.	0.	0.	0.
17.0000	0.	30.0000	250.0000	1058.7000
0.	0.	1837.6222	0.	1837.6222
0.	0.	0.	0.	0.
19.0000	0.	500.0000	467.0000	1205.0000
0.	0.	177626.6094	0.	177626.6094
0.	0.	0.	0.	0.
20.0000	0.	30.0000	140.0000	0.
0.	0.	11742.0789	0.	0.
0.	0.	11742.0789	0.	0.
21.0000	1.0000	[illegible].0000	70.0000	0.
0.	0.	11742.0789	0.	0.
0.	0.	11742.0789	0.	0.
22.0000	0.	30.0000	140.0000	0.
0.	0.	11742.0789	0.	0.
0.	0.	11742.0789	0.	0.
23.0000	2.0000	500.0000	467.0000	449.0000
0.	0.	1707.8826	1699.3857	0.
8.4969	0.	0.	0.	0.
24.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
25.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
26.0000	1.0000	15.0000	70.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
27.0000	0.	30.0000	335.0000	1205.0000
0.	0.	449.7310	0.	449.7310
0.	0.	0.	0.	0.
28.0000	0.	30.0000	250.0000	219.0000
0.	0.	449.7310	0.	449.7310
0.	0.	0.	0.	0.
29.0000	1.0000	15.0000	80.0000	0.
0.	0.	215918.3555	0.	0.
0.	215918.3555	0.	0.	0.
30.0000	0.	15.0000	80.0000	0.
0.	300.0000	215918.3555	0.	0.
0.	215918.3555	0.	0.	0.
31.0000	0.	500.0000	467.0000	1205.0000
0.	0.	3255.9161	0.	3255.9161
0.	0.	0.	0.	0.
32.0000	0.	30.0000	250.0000	1079.6000
0.	0.	3255.9161	0.	3255.9161
0.	0.	0.	0.	0.
34.0000	0.	500.0000	467.0000	1205.0000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
35.0000	2.0000	15.0000	3000.0000	0.
0.	0.	229115.8164	0.	0.
0.	0.	0.	229115.8164	0.
36.0000	1.0000	15.0000	70.0000	38.0000
0.	0.	2209.2014	2209.2014	0.
0.	0.	0.	0.	0.

Figure B5. Contd.

EQUIPMENT PARAMETERS MATRIX RUN 4 - FINAL

1.0000	0.	20000.0000	928.0000	80.0000
90.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
2.0000	0.	0.0001	0.0030	0.9700
650.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
3.0000	0.	70.0000	93.0000	996.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
4.0000	0.	70.0000	93.0000	996.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
5.0000	0.	1.0000	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
6.0000	0.	70.0000	93.0000	996.0000
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
8.0000	0.	0.8800	0.1200	0.
0.	200.0000	80.0000	449.4000	0.
0.	0.	0.	0.	0.
9.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
10.0000	0.	0.8800	0.1200	0.
0.	0.	80.0000	0.	0.
0.	0.	0.	0.	0.
11.0000	0.	0.4800	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
12.0000	0.	60.0000	95.0000	4.0000
45.0000	32.0000	26.0000	115.0000	109.0000
996.0000	0.	0.	0.	0.
13.0000	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.

Figure B6. Computer Calculations for Run 04 - Basic System Without Economizer, Order of Calculations Not Specified

STREAM VARIABLES MATRIX RUN 4 - FINAL

1.0000	0.	500.0000	680.0000	1344.0000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
2.0000	0.	2.0000	126.0000	1011.2000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
3.0000	1.0000	15.0000	80.0000	49.0000
0.	0.	8.4969	0.	0.
8.4969	0.	0.	0.	0.
4.0000	2.0000	15.0000	126.0000	94.0000
0.	0.	509.8157	0.	509.8157
0.	0.	0.	0.	0.
5.0000	0.	2.0000	126.0000	94.0000
62.4000	0.	171646.4492	171637.9512	0.
8.4969	0.	0.	0.	0.
6.0000	0.	30.0000	70.0000	0.
0.	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
7.0000	2.0000	30.0000	95.0000	0.
0.	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
8.0000	1.0000	15.0000	70.0000	0.
64.0000	0.	6403132.0000	0.	0.
0.	0.	0.	0.	6403132.0000
9.0000	0.	500.0000	467.0000	1205.0000
0.	0.	2041.6575	0.	2041.6575
0.	0.	0.	0.	0.
10.0000	0.	30.0000	250.0000	1058.7000
0.	0.	2041.6575	0.	2041.6575
0.	0.	0.	0.	0.
11.0000	0.	30.0000	126.0000	94.0631
62.4000	0.	171646.4492	171637.9512	0.
8.4969	0.	0.	0.	0.
12.0000	0.	500.0000	467.0000	1205.0000
0.	0.	104.7822	0.	104.7822
0.	0.	0.	0.	0.
13.0000	0.	30.0000	250.0000	1058.7000
0.	0.	104.7822	0.	104.7822
0.	0.	0.	0.	0.
14.0000	0.	30.0000	165.6349	133.7180
62.4000	0.	179336.0781	179327.5801	0.
8.4969	0.	0.	0.	0.
15.0000	0.	500.0000	165.6349	135.1128

Figure B5. Contd.

62.4000	0.	179336.0781	179327.5801	0.
8.4969	0.	0.	0.	0.
16.0000	0.	500.0000	467.0000	1205.0000
0.	0.	1837.6385	0.	1837.6385
0.	0.	0.	0.	0.
17.0000	0.	30.0000	250.0000	1058.7000
0.	0.	1837.6385	0.	1837.6385
0.	0.	0.	0.	0.
19.0000	0.	500.0000	467.0000	1205.0000
0.	0.	177628.1953	0.	177628.1953
0.	0.	0.	0.	0.
20.0000	0.	30.0000	140.0000	0.
0.	0.	11742.0950	0.	0.
0.	0.	11742.0200	0.	0.
21.0000	1.0000	15.0000	70.0000	0.
0.	0.	11742.0200	0.	0.
0.	0.	11742.0200	0.	0.
22.0000	0.	30.0000	140.0000	0.
0.	0.	11742.0950	0.	0.
0.	0.	11742.0950	0.	0.
23.0000	2.0000	500.0000	467.0000	449.0000
0.	0.	1707.8826	1699.3857	0.
8.4969	0.	0.	0.	0.
24.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
25.0000	0.	30.0000	140.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
26.0000	1.0000	15.0000	70.0000	0.
0.	0.	1455.3838	0.	0.
0.	0.	1455.3838	0.	0.
27.0000	0.	30.0000	335.0000	1205.0000
0.	0.	449.7290	0.	449.7290
0.	0.	0.	0.	0.
28.0000	0.	30.0000	250.0000	219.0000
0.	0.	449.7290	0.	449.7290
0.	0.	0.	0.	0.
29.0000	1.0000	15.0000	80.0000	0.
0.	0.	215917.3926	0.	0.
0.	215917.3926	0.	0.	0.
30.0000	0.	15.0000	80.0000	0.
0.	300.0000	215917.3926	0.	0.
0.	215917.3926	0.	0.	0.
31.0000	0.	500.0000	467.0000	1205.0000
0.	0.	3255.9016	0.	3255.9016
0.	0.	0.	0.	0.
32.0000	0.	30.0000	250.0000	1079.6000
0.	0.	3255.9016	0.	3255.9016
0.	0.	0.	0.	0.
34.0000	0.	500.0000	467.0000	1205.0000
0.	0.	169938.5684	0.	169938.5684
0.	0.	0.	0.	0.
35.0000	2.0000	15.0000	3000.0000	0.
0.	0.	229114.8711	0.	0.
0.	0.	0.	229114.8711	0.
36.0000	1.0000	15.0000	70.0000	38.0000
0.	0.	2209.2014	2209.2014	0.
0.	0.	0.	0.	0.

Figure B5. Contd.